UNIVERSIDADE FEDERAL DE SÃO CARLOS
CENTRO DE CIÊNCIAS BIOLÓGICAS E DA SAÚDE
PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA E RECURSOS NATURAIS

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# PALEOBIOLOGY OF THE ITAJAÍ BASIN (EDIACARAN, SANTA CATARINA, BRAZIL): EVOLUTIONARY, PALEOECOLOGICAL AND TAPHONOMICAL IMPLICATIONS

PALEOBIOLOGIA DA BACIA DE ITAJAÍ (EDIACARANO, SANTA CATARINA, BRASIL): IMPLICAÇÕES EVOLUTIVAS, PALEOECOLÓGICAS E TAFONÔMICAS

SÃO CARLOS – SP
2020

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Tese apresentada ao Programa de Pós-Graduação em Ecologia e Recursos Naturais, da Universidade Federal de São Carlos, para obtenção do título de doutor em Ciências, área de concentração em Ecologia e Recursos Naturais.

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São Carlos-SP

2020

UNIVERSIDADE FEDERAL DE SÃO CARLOS

Centro de Ciências Biológicas e da Saúde
Programa de Pós-Graduação em Ecologia e Recursos Naturais

## Folha de Aprovação

Defesa de Tese de Doutorado do candidato Bruno Becker Kerber, realizada em 04/06/2020.

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Homologado(a) pela CPG
565ª reunião 17/06/2020
CPG - PPGERN/UFSCar

O presente trabalho foi realizado com apoio da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Código de Financiamento 001.

O Relatório de Defesa assinado pelos membros da Comissão Julgadora encontra-se arquivado junto ao Programa de Pós-Graduação em Ecologia e Recursos Naturais.

*In dedication to my parents, Elaine Becker Kerber and Gilmar Kerber*

## ACKNOWLEDGEMENTS

This work had the fundamental support of the “Fundação de Amparo à Pesquisa do Estado de São Paulo” (FAPESP) within the projects: 2016/01827-4 e 2018/21886-0. It also had the support of Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) during the initial months of the doctorate.

As it is for almost every scientific endeavor, the results presented here are a consequence of an intense and productive scientific collaboration that I had the opportunity to realize with several great scientists.

I am profoundly grateful to my mentor and scientific inspiration, Mírian Liza Alves Forancelli Pacheco. A lot of this work, and of what I have learned throughout these years, would not have happened without her teachings, her support and her dedication as a scientist and as an advisor.

I am also thankful to my co-advisor Paulo Sergio Gomes Paim (UNISINOS) for all that I learned about geology and the Itajaí Basin; and to Ana Zucatti, the pioneer in Itajaí Basin paleontology; both great scientists and friends that I was lucky to meet.

I am grateful for all the institutions that provided the necessary infrastructure for the development of this work, including: the Brazilian Synchrotron Light Laboratory, under the SR-μXRF (20170438, 20171031, 20180327) and μ-CT (IMX 20180137) projects; the Brazilian Nanotechnology National Laboratory, under the SEM/EDS (21836 e 23684) and μ-CT (20415). I thank very much the support of the laboratory of thin section preparation at UNISINOS, which provided dozens of thin sections for this work. I also thank the thin section laboratory of the Geosciences Institute at UNESP (Rio Claro) and the professor Luiz Sergio Amarante Simões.

I am deeply grateful to prof. Abderrazak El Albani, for receiving and advising me during the BEPE period at the Université de Poitiers (France), and for all the opportunities I had during my stay in his lab. I am also grateful to prof. Alain Meunier, for the collaboration, as well as for everything I learned about clays from him. I would like to thank Kurt Konhauser for his helpful and detailed insights in the work about the preservation of the Itajaí Basin fossils. I also thank very much Marc Laflamme for all the prodigious help in the work about the filamentous structures.

I am extremely grateful to my dear friend Ahmed Abd Elmola, for the amazing scientific collaboration, and for the good friendship that we were able to develop during my stay in France.

I would like also to thank Claude Fontaine for all his help with the x-ray diffraction analyses. I thank also all the technical support of Arnaud Mazurier, Julien Brunet, Claude Laforest, and Celine Boissard.

I am grateful to Milene Figueiredo for all her help and kindness during the palynological investigation developed in collaboration with Petrobras, as well as to the technical help of Igor Augusto Nascimento de Almeida and Gilton Braz de Aquino Filho.

I am profoundly grateful to the professors and the student representatives of the postgraduation commission of the PPGERN, which supported the development of my sandwich doctorate, in special to prof. Ana Lombardi, prof. Marcelo Adorna, Roberta Freitas and Raphael Machado.

I am profoundly thankful to my longtime friends Gustavo Prado and Gabriel Ladeira Osés, with whom I had many essential scientific discussions; and to my friend Gabriel Barros for the great scientific collaboration, and for all the trajectory we shared within the paleontological world. I thank also all the help of Ilana Lehn during the experiments at the Brazilian synchrotron. I am also grateful to my brother Pedro Becker Kerber, and to my sister Bianca Becker Kerber, for all their help in some steps of this work.

I am eternally grateful to the unrestricted support of my parents throughout all these years. I own much of my formation as a scientist and as a person to them, my father Gilmar Kerber, and my mother Elaine Becker Kerber.

At last, but not least, I would like to thank all the citizens of Apiúna (SC) that helped me in one way or another during the time-consuming field works.

## AGRADECIMENTOS

Este trabalho teve o apoio fundamental da Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) dentro dos projetos: 2016/01827-4 e 2018/21886-0. Também teve o apoio do Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) durante os primeiros meses do doutorado.

Como é para quase todo trabalho científico, os resultados apresentados aqui são frutos também de uma intensa e produtiva colaboração científica que eu tive a oportunidade de realizar com diversos ótimos cientistas.

Sou profundamente grato à minha mentora e inspiração científica Mírian Liza Alves Forancelli Pacheco. Muito desse trabalho, e do que aprendi ao longo dos anos, não teria acontecido sem os seus ensinamentos, seu apoio e sua dedicação como cientista e orientadora.

Agradeço também a toda a ajuda do meu coorientador prof. Paulo Sergio Gomes Paim (UNISINOS), por tudo que aprendi sobre geologia e sobre a Bacia de Itajaí; e à Ana Zucatti, pioneira na paleontologia da Bacia de Itajaí; ambos grandes cientistas e amigos que tive a sorte de conhecer.

Sou grato a todas as instituições que forneceram a infraestrutura necessária para o desenvolvimento deste trabalho, incluindo: Laboratório Nacional de Luz Síncrotron (LNLS), dentro dos projetos SR-XRF (20170438, 20171031, 20180327), e μ-CT (IMX 20180137); Laboratório Nacional de Nanotecnologia (LNNano), projetos MEV/EDS (21836 e 23684) e μ-CT (proposal 20415). Sou muito grato também ao laboratório de preparação de lâminas delgadas da UNISINOS, o qual providenciou dezenas de lâminas delgadas para este trabalho. Também agradeço ao laboratório de preparação de lâminas do Instituto de Geociências da UNESP (Rio Claro) e ao professor Luiz Sergio Amarante Simões.

Sou imensamente grato ao prof. Abderrazak El Albani por me receber e me orientar durante o período BEPE na Université de Poitiers (França), e por todas as oportunidades que tive durante minha estadia em seu laboratório. Também agradeço profundamente ao prof. Alain Meunier por ter aberto a oportunidade de desenvolver esse trabalho em conjunto com o prof. Abderrazak, assim como por tudo que aprendi

sobre argilas. Eu gostaria de agradecer a Kurt Konhauser pelos seus úteis e detalhados insights no trabalho sobre a preservação dos fósseis da Bacia de Itajaí. Eu também sou muito grato a Marc Laflamme por toda a prodigiosa ajuda no trabalho sobre as estruturas filamentosas.

Sou extremamente grato ao meu amigo Ahmed Abd Elmola por toda a incrível colaboração científica e pela ótima amizade que pudemos desenvolver ao longo da minha estadia na França.

Agradeço a Claude Fontaine, por toda a ajuda que me ofereceu durante as análises de difração de raios-X. Agradeço também a Arnaud Mazurier, Julien Brunet, Claude Laforest, e Celine Boissard, por todo o apoio técnico que recebi na Université de Poitiers.

Agradeço à Milene Figueiredo por toda a ajuda e gentileza durante as análises palinológicas desenvolvidas em colaboração com a Petrobrás, assim como ao apoio técnico de Augusto Nascimento de Almeida e Gilton Braz de Aquino Filho.

Sou extremamente grato aos professores e representantes discentes da comissão de pós-graduação do PPGERN, que apoiaram a possibilidade de desenvolver o doutorado sanduíche, em especial à profa. Ana Lombardi, prof. Marcelo Adorna, Roberta Freitas e Raphael Machado.

Aos meus amigos de longa data e ótimos cientistas Gustavo Prado e Gabriel Ladeira Osés, com os quais muitas discussões foram de grande ajuda para o desenvolvimento deste trabalho. Agradeço também a Gabriel Barros, por toda a ajuda e ótima colaboração científica que pudemos desenvolver ao longo da nossa trajetória dentro da paleontologia. Eu agradeço também a ajuda de Ilana Lehn durante os experimentos no Síncrotron. Sou grato também ao meu irmão Pedro Becker Kerber, e minha irmã Bianca Becker Kerber, pela ajuda em determinadas etapas deste trabalho.

Sou eternamente grato ao apoio irrestrito dos meus pais ao longo de todos esses anos. Devo muito da minha formação como cientista e como pessoa a eles, meu pai Gilmar Kerber, e minha mãe Elaine Becker Kerber.

Por fim, gostaria de agradecer a todos os cidadãos de Apiúna que de alguma forma ajudaram nos longos trabalhos de campo.

*“We are here because one odd group of fishes had a peculiar fin anatomy that could transform into legs for terrestrial creatures; because the earth never froze entirely during an ice age; because a small and tenuous species, arising in Africa a quarter of a million years ago, has managed, so far, to survive by hook and by crook. We may yearn for a "higher" answer--but none exists. This explanation, though superficially troubling, if not terrifying, is ultimately liberating and exhilarating. We cannot read the meaning of life passively in the facts of nature. We must construct these answers ourselves-from our own wisdom and ethical sense. There is no other way.”*

Stephen Jay Gould, Life Magazine, 1988

**SUMMARY**

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## ABSTRACT

New studies on the geologic history of Earth are increasingly revealing the complex relationships among evolutionary patterns, diversification of major groups, and environmental changes. In the fossil record of the Ediacaran Period (635–541 Ma), the appearance of macroscopically complex organisms and animals resulted in major modifications in the environment, setting the stage for the subsequent “Cambrian explosion” and the development of Phanerozoic-style ecosystems. The Ediacaran biota can be found in several localities throughout the world, and researchers on this subject are able now to divide it in mainly three Assemblages: Avalon, White Sea and Nama. Compared to other deposits around the world, studies on South American Ediacaran fossils are still in their early stages, but already show a great potential to understand the evolution of early complex life. In this context, this work aimed to investigate the taxonomy, taphonomy and age of the poorly known fossils from the Itajaí Basin (Santa Catarina, southern Brazil), as well as its relationships to other coeval fossiliferous strata. For that, a multi-approach investigation was conducted, using diverse techniques, such as: stereomicroscopic investigation; petrography; U/Pb radiometric dating (SHRIMP); scanning electron microscopy (SEM) and dispersive energy spectroscopy (EDS); computerized microtomography (µCT); and Raman and infrared spectroscopy. The results of this work are presented here in three main published and/or submitted articles regarding: [I] the description of the Itajaí Biota and its age; [II] the taphonomic characteristics of the ‘Ediacaran-style’ preservation at the Itajaí Basin; and [III] the nature of microbial filaments. In Article 1, it is reported the presence of Ediacaran soft-bodied organisms, such as *Palaeopascichnus*, discoidal forms (*Aspidella* and *Nimbia*), as well as abundant microbial mat features (e.g., reticulated tufts, Arumberia, and wrinkles). Moreover, the age of the Itajaí Basin is further constrained by U/Pb radiometric dating of volcanic tuffs, giving a depositional age ca. 563 Ma and setting this Ediacaran biota as one of the oldest in Gondwana. In Article 2, it is presented a detailed investigation on the microbial filaments and their possible affinities with giant filamentous sulfide-oxidizing bacteria, such as the modern *Beggiatoa*. This has great implications for understanding the biotic and geochemical context during Ediacaran times. In Article 3, it is provided a model to the fossilization mechanisms of the Itajaí Basin, in which the micro and macrofossils would have been

preserved by volcanic and microbial activity. This work shows for the first time robust evidences for the role of clay authigenesis in the early diagenesis of fossils. In sum, this thesis provides a comprehensive take on the paleobiology, taphonomy, and age of the Ediacaran Itajaí Biota, showing that these deposits are of key importance in studies on early macroscopic complex lifeforms of the fossil record.

**Key words:** Avalon Assemblage. Ediacaran Biota. Discoidal Fossils. Pseudofossils. Microbially Induced Sedimentary Structures (MISS). Taphonomy. Clay authigenesis. Illite

## RESUMO

Novos estudos sobre a história geológica da Terra estão cada vez mais revelando as relações complexas que existem entre padrões evolutivos, diversificação dos principais grupos de organismos, e mudanças ambientais. No registro fóssil do Período Ediacarano (635–541 Ma), o aparecimento de organismos macroscópicos complexos e animais resultaram em grandes modificações no ambiente, preparando o palco para a subsequente "explosão Cambriana" e o desenvolvimento de ecossistemas típicos do Fanerozoico. A biota ediacarana pode ser encontrada em várias localidades globalmente, e agora os pesquisadores do tema são capazes de dividi-la em três principais assembleias: Avalon, White Sea e Nama. Mesmo assim, comparado com outros depósitos globalmente, estudos sobre fósseis ediacaranos na América do Sul ainda estão em suas fases iniciais, mas já mostram um grande potencial para a compreensão da evolução inicial de organismos complexos. Este trabalho teve como objetivo investigar a taxonomia, tafonomia e idade dos fósseis da Bacia de Itajaí (Santa Catarina, Brasil), assim como suas possíveis relações com outros estratos fossilíferos contemporâneos. Para tanto, uma investigação de abordagem múltipla foi conduzida, usando diversas técnicas, como: estereomicroscopia; petrografia; datação radiométrica por U/Pb (SHRIMP); microscopia eletrônica de varredura (MEV) e espectroscopia de energia dispersiva (EDS); microtomografia computadorizada (µCT); e espectroscopia Raman e de infravermelho. Os resultados deste trabalho estão apresentados aqui em três artigos publicados e/ou submetidos, considerando: [I] a descrição e idade da biota de Itajaí; [II] os processos tafonômicos da preservação do 'tipo Ediacarana' na Bacia de Itajaí; e [III] a natureza dos filamentos micrométricos. No Artigo 1, é reportada a presença de organismos de corpo mole, como *Palaeopascichnus*, formas discoides (*Aspidella* e *Nimbia*), assim como abundantes texturas de esteiras microbianas (e.g., *tufts* reticulados, Arumberia e *wrinkles*). Além disso, a idade da Bacia de Itajaí é melhor restringida por datação radiométrica U/Pb de tufos vulcânicos, resultando numa idade de deposição de *ca*. 563 Ma e definindo esta biota ediacarana como uma das mais antigas do Gondwana. No Artigo 2, é apresentada uma detalhada investigação sobre os filamentos microbianos encontrados e suas possíveis afinidades com bactérias filamentosas gigantes oxidantes de enxofre, como o moderno gênero *Beggiatoa*.

Estes resultados trazem implicações para a compreensão do contexto biótico e geoquímico durante o Ediacarano. No Artigo 3, é fornecido um modelo sobre os mecanismos de fossilização na Bacia de Itajaí, no qual micro e macrofósseis teriam sido preservados por meio de atividade vulcânica e microbiana. Este trabalho mostra pela primeira vez evidências robustas para o papel da autigênese de argilominerais na diagênese inicial de fósseis. Em resumo, esta tese fornece uma visão ampla sobre a paleobiologia, tafonomia e idade da bacia ediacarana de Itajaí, mostrando que estes depósitos são de importância chave para estudos sobre as primeiras formas de vida macroscópicas e complexas do registro fóssil.

**Palavras-chave**: Assembleia Avalon. Biota Ediacarana. Fósseis Discoides. Pseudofósseis. Estruturas Sedimentares Microbialmente Induzidas (MISS). Tafonomia. Autigênese de Argila. Ilita.

# 1 INTRODUCTION

## 1.1 THE EDIACARAN PERIOD

The organisms that appear in the fossil record of the Ediacaran Period (636–539 Ma) have often been considered as the prelude to the so-called “Cambrian explosion”. However, several studies are now showing the paleobiological peculiarities of the Ediacaran assemblages, changing our views about early animal evolution, and the dawn of macroscopic and complex organisms (Xiao and Laflamme, 2009; Ding et al., 2019; Dunn and Liu, 2019; Ivantsov et al., 2019). During this time, a diverse and global biota of soft-bodied organisms of unknown affinity developed in benthic ecosystems that set the stage for major subsequent biotic transformations (Fig. 1).

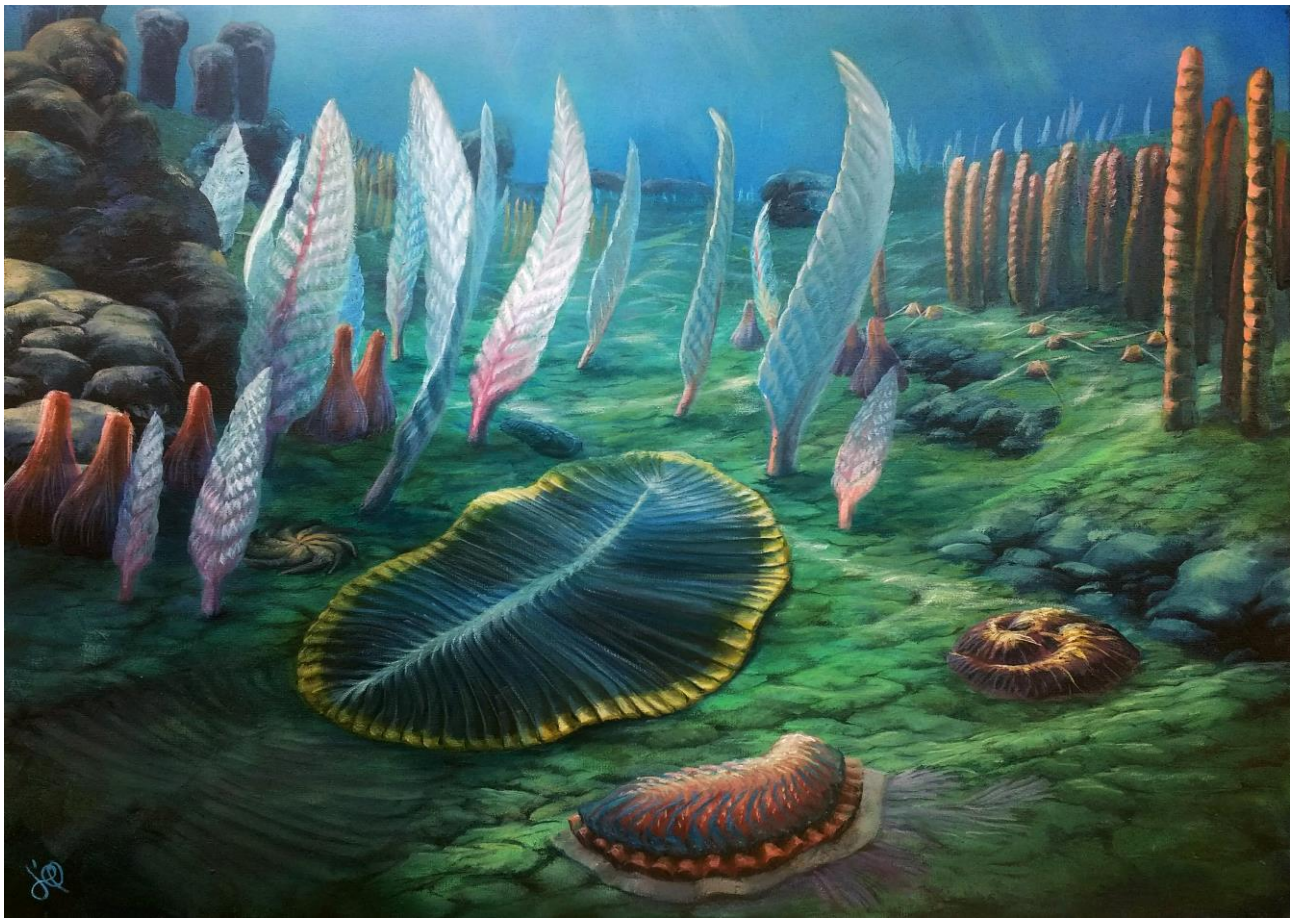

**Fig. 1**. Artistic reconstruction of an Ediacaran seafloor (White Sea Assemblage) containing some of the typical and enigmatic Ediacaran soft-bodied organisms. Art by Julia Soares d’Oliveira.

The Ediacaran Period is broadly interspaced between two large events: the end of the Marinoan glaciation, marked by the deposition of the cap carbonates (~635 Ma); and the Cambrian biological radiation, or the 'Cambrian explosion'. The limit of the Ediacaran/Cambrian is still discussed, but it is usually regarded as the first appearance of the ichnofossil *Treptichnus pedum*, *ca*. 541 Ma (Buatois, 2018).

Although there is the traditional delimitation of the Ediacaran in three main assemblages (Waggoner, 2003; Narbonne, 2005) (see below), still there are no formal subdivisions for this time period that allow detailed correlations between geologic units throughout the world (Narbonne et al., 2012). Other attempts to create a biostratigraphic framework for the Ediacaran have mostly relied on acritarch biozones. For example, Grey (Grey, 2005) defined five acritarch biozones for the Ediacaran successions of Australia, while other researchers suggested two biozones for the Ediacaran deposits of China: a lower biozone dominated by *Tianzhushania spinosa*; and an upper biozone defined by *Tanarium conoideum – Hocosphaeridium scaberfacium – H. anozos* (McFadden et al., 2009; Liu et al., 2013b; Xiao et al., 2014). However, although these biozones are useful for regional correlations, their use for understanding the global biostratigraphy of the Ediacaran still need to be further investigated.

Despite this lack of biostratigraphic zonations, the Ediacaran Period presents taxonomic, ecological, and taphonomic characteristics that are singular in the fossil record (Shen et al., 2008; Xiao and Laflamme, 2009). As pointed out above, these biotic events are evidenced in three assemblages: the Avalon, White Sea and Nama clusters. Other important fossiliferous deposits include those from the Doushantuo Formation of China, with the embryo-like fossils (Yin et al., 2016), and the Lantian Formation, with the diverse macroalgae and putative metazoans (Yuan et al., 2011; Wan et al., 2016).

The Avalon localities (~570–559 Ma) record the appearance of the first macroscopic complex soft-bodied organisms in deep-marine settings, supposedly bellow the photic zone (Liu et al., 2015). The rise of these early ecosystems has been linked to increasing levels of oxygen (Canfield et al., 2007), and some works revealed that this biotic event can be characterized by an explosion of morphospace (Shen et

al., 2008). The Avalonian communities were dominated by sessile benthic macroorganisms characterized by frondose morphologies (e.g., rangeomorphs and arboreomorphs) of unknown affinities, but largely considered as stem-group metazoans. Other more elusive macrofossils also occur, including putative sponges (e.g., *Thectardis* (Sperling et al., 2011); but see (Antcliffe et al., 2014)) and cnidarians (e.g., *Haootia quadriformis* (Liu et al., 2014); but see (Miranda et al., 2015)), as well as possible ichnofossils. Microbial mat features are observed, but are uncommon in the deep settings of the Avalonian deposits (Droser et al., 2017), where, instead, dense fabric of submillimeter- to millimeter-sized filaments are present (Liu et al., 2016a). Some of these filaments were recently observed to connect the holdfast of frondose taxa, which led the authors to interpreted them as stolonic connections of the macroorganisms (Liu and Dunn, 2020). However, other interpretations may also apply to similar filamentous fossils (see Article 3 of this thesis).

The younger White Sea paleocommunities (~558–550 Ma) developed mostly on photic and shallower settings, compared to the Avalonian ones (Grazhdankin, 2004, 2014). During this time, further evolutionary and ecologic innovations occurred. Especially, it is in the White Sea deposits that abundant evidences of motility can be observed, as showed by the horizontal trace fossils and the feeding traces of mobile organisms. Dickinsoniomorphs, erniettomorphs, kimberellomorphs, and other enigmatic forms also appear for the first time during the White Sea. Of special interest for studies on early animal evolution is the fossil *Kimberella*, one of the few Ediacaran taxa usually considered as a crown-group metazoan, probably a mollusk (Fedonkin et al., 2007). This bilateral form is frequently associated with scratch-marks on bedding planes that are interpreted as their feeding traces (Ivantsov et al., 2019). The White Sea localities also bear abundant evidence for the development of microbial mats, a feature uncommon and controversial in the previous Avalon ecosystems.

The Nama paleocommunities (550–539 Ma) marked the final stage of the Ediacaran biota, where the ecosystems seem to have suffered a significant loss in diversity (Darroch et al., 2015a). This biota also presents rangeomorphs and erniettomorphs, but it is mainly characterized by the appearance of several tubular animals (‘*Wormworld fauna*’), including mineralized metazoans, and increasingly complex ichnofossils (Schiffbauer et al., 2016; Wood, 2018). Finally, the Ediacaran/Cambrian transition shows the demise of this Ediacaran biota, with only

some proposed surviving taxa in Cambrian deposits (Jensen et al., 1998; Hagadorn et al., 2000).

## 1.2 THE PRESERVATION STYLES OF THE EDIACARAN BIOTA

Although there are reports of Ediacaran fossils preserved by kerogenization (Xiao et al., 2002), pyritization (Cai and Hua, 2007; Cai et al., 2010; Guan et al., 2017), and, possibly, aluminosilicification (Anderson et al., 2011; Cai et al., 2012; MEYER et al., 2012), the Ediacaran Period is widely recognized by the common preservation of the soft-bodied macro-organisms as molds and casts in siliciclastic rocks. This 'Ediacaran-style' preservation can be further divided in the 'Conception' (positive relief under ash layers), 'Flinders' (positive and negative epirelief), and 'Nama-styles' (three-dimensionally within sandstones).

The Conception style is basically defined by the preservation of the macro-organisms in positive epirelief bellow ash-fall deposits (Seilacher, 1992; Narbonne, 2005). This type of fossilization is observed in the deep-marine Avalon paleocommunities of Newfoundland and England. However, recent works (Liu, 2016) have suggested that, instead of volcanic burial, the most likely mechanism for their fossilization was the 'death-mask' model.

The 'death mask' hypothesis was firstly proposed by Gehling (Gehling, 1999) to explain the moldic preservation of the 'Flinders-style'. In this model, the author suggested that the presence of microbial mats stabilized the seafloor, limited the diffusion of ions, and (after a burying event) led to the precipitation of iron sulfides as a result of microbial metabolism, forming an early diagenetic sole veneer that replicated the buried macro-organisms and microbial mats. Although recent works supported the death mask model for Avalon and White Sea localities (Liu, 2016; Liu et al., 2019), still this taphonomic scenario remains contentious to other researchers.

Other hypotheses were also raised for the 'Ediacaran-style' preservation. Tarhan et al. (Tarhan et al., 2017) suggested that silica-rich oceans would have promoted an early silica cementation of the fossil-bearing deposits. On the other hand, Bobrovskiy et al. (2019a) provided evidence for the rheological model initially raised by Wade (Wade, 1968), where the different properties (e.g., viscosity) of sediments

(over- and underlying decaying organisms) were essential to their positive epirelief preservation.

## 1.3 THE EDIACARAN MACROFOSSILS OF SOUTH AMERICA

Ediacaran fossiliferous deposits are known to occur in several localities worldwide. However, despite the presence of several Ediacaran-age geologic units in South America, only few fossil taxa were reported until now. This more likely reflects the lack of more studies (compared to other Ediacaran deposits) than a true paleontological phenomenon. Nonetheless, the importance of the South America ediacaran record has been increasingly demonstrated by recent works.

The most known Ediacaran localities in South America are those bearing the Nama-type organisms of the latest Ediacaran. These are exemplified by a number of carbonate and siliciclastic successions, such as: the Corumbá and Bambuí Groups in Brazil (Warren et al., 2014; Becker-Kerber et al., 2017); the Tagatiya Guazu Formation in Paraguay (Warren et al., 2011); the Arroyo del Soldado Group in Uruguay (Gaucher et al., 2003); and possibly the Sierras Bayas Group in Argentina (Gaucher et al., 2005). One of the main things these units have in common is the presence of the biomineralized genus *Cloudina*, often regarded as a terminal Ediacaran index taxon. Other macrofossils include: *Corumbella* (Tamengo, Sete Lagoas, and Tagatiya Guazu formations) (Warren et al., 2014, 2017; Pacheco et al., 2015); *Paraconularia* (Tamengo Formation) (Van Iten et al., 2014); *Namacalathus* (Tagatiya Guazu Formation) (Warren et al., 2017); the putative tubular fossils *Soldadotubulus* and *Waltheria* (Yerbal Formation) (Gaucher, C., Sprechmann, 1999); and the algae *Vendotaenia* (Tamengo Formation), *Eoholynia* and *Tawuia* (Guaicurus Formation) (Gaucher et al., 2003). The reported *Vendotaenia* from the Cerradinho and Bocaina Formations (see (Gaucher et al., 2003)), recovered by acid macerations, are highly fragmented and poorly preserved, and their identification within this genus is considered here as controversial.

Soft-bodied Ediacaran fossils are rare in South America successions, and as discussed in the first article of this thesis, they are highly problematic. Yet, it is worthy to mention the proposed presence of *Nemiana* from the (Cambrian?) Puncoviscana Formation in Argentina (Aceñolaza and Aceñolaza, 2007; Aceñolaza, 2012); putative *Aspidella* discs from the Cerro Negro Formation in Argentina (Arrouy et al., 2016) (but

see (Inglez et al., 2019)); and possible *Aspidella*, *Intrites*, and *Sekwia* from the Camaquã Basin in Brazil (Netto, 2012).

Apart from these occurrences, some preliminary works reported the supposed presence of Ediacaran soft-bodied organisms in the Itajaí Basin (IB – southern Brazil) (Rosa, 2005). Although most of the works on the paleontology of the Itajaí basin remained unpublished until now, they showed the great potential of this basin for studies on the early evolution of complex large organisms.

In this thesis, I bring a new look into the paleontology of the poorly known IB, showing the presence of undoubtful soft-bodied ediacarans (e.g., *Palaeopascichnus*), as well as discoidal forms, microbial filaments, pseudofossils and several morphotypes of microbially induced sedimentary structures (MISS). The age of the Itajaí basin is also further refined by new U/Pb radiometric dating of tuff levels (~563 Ma), setting this Ediacaran fossil record as one of the oldest in Gondwana. The high-fidelity preservation found in some of the fossiliferous levels is also addressed and a new model for the ‘Ediacaran-style’ preservation is proposed, where volcanic and microbial activity played major roles during the fossilization of the biota. Finally, it is presented a detailed discussion on the nature of the IB microbial filaments, and their implications for understanding the Ediacaran biological and geochemical evolution.

## 2 GOALS

The aims of this work were:

**A)** To investigate the taxonomic composition of the Itajaí Basin fossil biota;

**B)** To analyze the evolutionary and paleoecological context of this biota;

**C)** To study the paleoenvironment and fossilization context of the macroscopic fossils, with relation to the association with microbially induced sedimentary structures (MISS) and the taphonomic conditions of the early diagenesis;

**D)** To compare the Itajaí biota with other correlate units in Brazil and other places in the world, such as Australia, England and Canada.

## 3 ARTICLE ONE

*Published in Gondwana Research*

# The oldest record of Ediacaran macrofossils in Gondwana (~563 Ma, Itajaí Basin, Brazil)

**Abstract**. The Avalon biota (Ediacaran Period, 570–559 Ma) marks the first appearance of macroscopic and complex benthic communities in the fossil record. This assemblage is known from a few localities worldwide, mainly in Canada and England. Here, we report for the first time the presence of Ediacaran macrofossils in deposits of similar age from Gondwana (Itajaí Basin, southern Brazil). Our new radiometric date (~563 Ma) indicates that the Itajaí Basin can be chronocorrelated with the classic Avalonian deposits and thus represents one of the oldest records of the Ediacaran biota in Gondwana. We describe the presence of the Ediacaran genus *Palaeopascichnus*, as well as discs (*Aspidella* and *Nimbia*), and other problematic forms. Contrary to the deep-marine macroorganisms of the Avalon Assemblage, the Itajaí fossils are associated with abundant and exceptionally preserved three-dimensional microbial mats and microbially induced sedimentary structures (MISS) in relatively shallow settings (upper slope and distal delta front deposits). In this sense, the Itajaí biota could represent early adaptations of benthic macrobiota to the shallower and more photic environments that characterize the later White Sea Assemblage.

## 1. Introduction

The first fossil evidence of macroscopic complex life forms is preserved in rocks associated with deep aphotic environments in the middle-late Ediacaran Period (Liu et al., 2015). The appearance of this Ediacaran biota marked the development of macroscopic benthic ecosystems characterized by an “explosion” of morphospace (i.e., Avalon biota) (Shen et al., 2008), including possible stem-group metazoans Period (Liu et al., 2015). Subsequent biotas include the White Sea and Nama Assemblages, which have distinct biotic compositions and further evolutionary

innovations (e.g., mobility and skeletonized animals, respectively) and were associated with shallow waters and photic zones (Grazhdankin, 2004; Boag et al., 2016).

Despite this knowledge, the mechanisms and biases behind the transitions among these biotas still need to be better understood. It is likely that both biological and environmental changes played a synergic role in ecosystem structuration during the Ediacaran. Specifically, the Avalon and White Sea biotas differ dramatically in the sense that the latter contains the first macroscopically complex organisms that were adapted to shallow waters and were associated with abundant textured organic surfaces (Droser et al., 2017).

Studies on the Avalonian biotas have mostly been restricted to the widely investigated rocks in Canada and England (Ford, 1958; Misra, 1969; Boynton and Ford, 1995; Narbonne and Gehling, 2003; Hofmann et al., 2008; Narbonne et al., 2014; Liu et al., 2015). Therefore, exploring the paleontological potential of other coeval deposits is essential to developing a more complete picture of the early evolution of macroscopic life. To date, Ediacaran units in South America bearing putative soft-bodied taxa have been reported only in deposits near the Ediacaran-Cambrian transition (Gaucher, 2018) and require further investigations regarding their proposed body fossil content (Inglez et al., 2019).

One geologic unit with great potential for studies on Ediacaran biota is the Itajaí Basin (IB). This geologic unit has long been controversial in terms of its paleontological record, mostly due to scarce studies. Previous and mostly unpublished works have suggested the presence of Cambrian (*Chancelloria* and *Choia*) and Ediacaran taxa (*Aspidella*), as well as putative ichnofossils such as *Diplocraterium*, *Helmintoidichnites*, and *Oldhamia* (Da Rosa et al., 1997; Leipnitz et al., 1997; Paim et al., 1997). These claims have led to some uncertainty about the age of the basin since radiometric dating suggested an upper Neoproterozoic age (Guadagnin et al. 2010; Basei et al. 2011 and references therein).

This study reports new fossil findings and geochronological data for the Itajaí Group. Here, we show the presence of macroorganisms, as well as putative animals, and abundant microbially induced sedimentary structures (MISS) associated with settings that are shallower than those of other Avalonian deposits. In this sense, the

Itajaí biota can be considered a key locality for understanding the colonization of shallower (and possibly photic) environments by complex Ediacaran organisms.

## 2. Geological context

During the late to post-orogenic stages of the Pan-African-Brasiliano Orogeny (~ 600 – 540 Ma), several sedimentary basins formed as a result of the collision of the Rio de la Plata, Congo and Kalahari cratons (Gresse et al., 1996). They include the Itajaí (Guadagnin et al., 2010; Basei et al., 2011), Camaquã (Paim et al., 2000; Netto, 2012), Arroyo del Soldado (Gaucher, 2000; Blanco et al., 2009) and Nama (Saylor et al., 1995; Grotzinger et al., 1995) basins (Supplementary Fig. 1), among others, and the IB is the focus of this work.

The E-NE-elongated IB is interpreted as a foreland basin (Rostirolla, 1991; Rostirolla et al., 1992; Gresse et al., 1996; Guadagnin et al., 2010) related to the Dom Feliciano Belt (DFB) in Santa Catarina State (Supplementary Fig. 1). The DFB comprises, from east to west, the Florianópolis Magmatic Arc, the metavolcano-sedimentary Brusque Complex and the foreland IB. To the northwest, the IB covers the Santa Catarina Granulite Complex, a tectonically stable area related to the Luis Alves Microplate (Guadagnin et al., 2010; Basei et al., 2011) (Fig. 1). The IB contains a thick siliciclastic succession, with minor volcaniclastic strata, that was deposited between 572 and 549 Ma (Guadagnin et al., 2010). This succession includes alluvial, deltaic and shallow- to deep-marine strata organized into five depositional sequences (adapted from (Fonseca, 2004) and (Teixeira et al., 2004) (Fig. 1)).

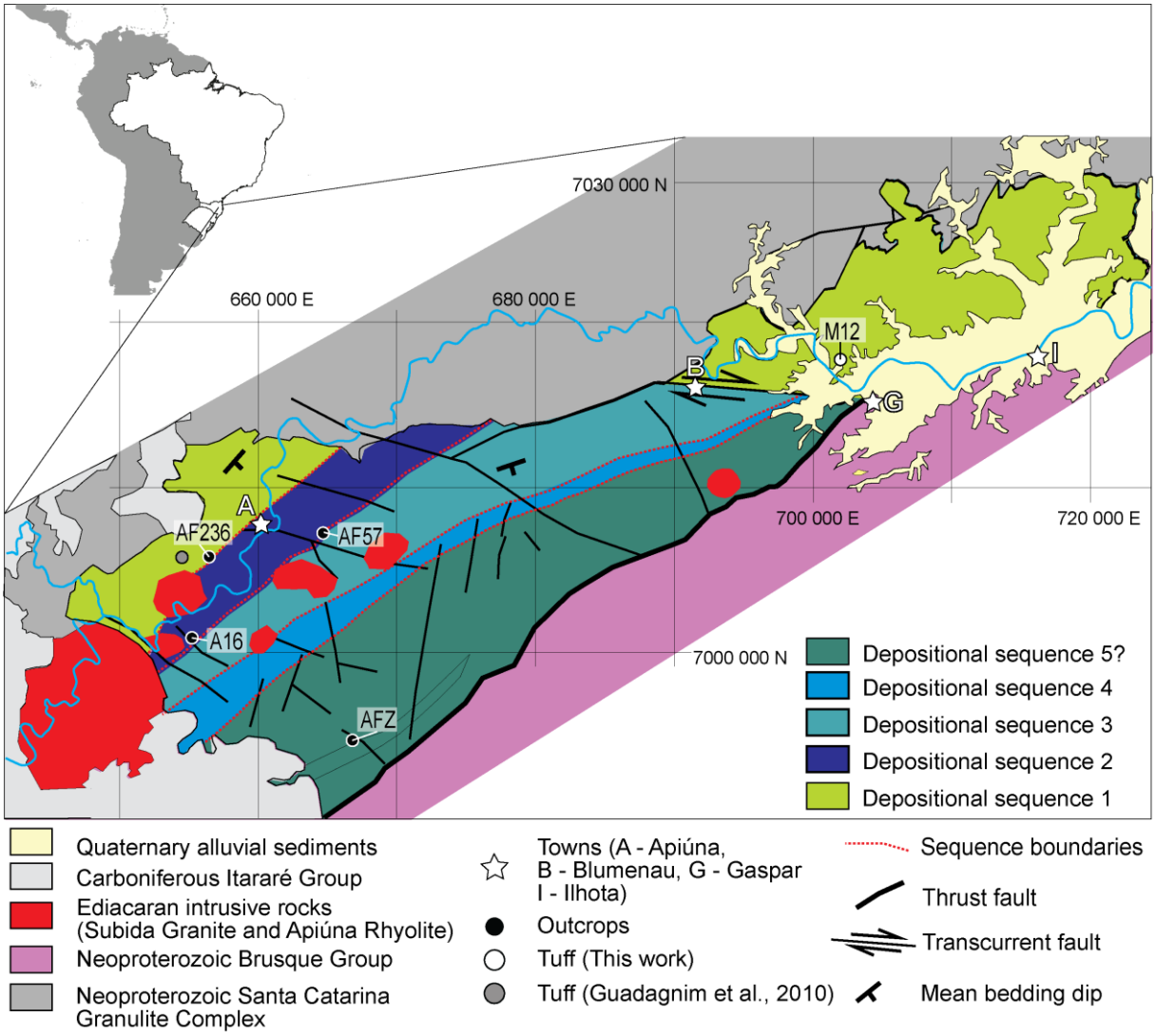


**Fig. 1.** Simplified geological map of the Itajaí Basin showing the main depositional sequences (DS) (modified after Fonseca, 2004 and Teixeira et al., 2004) and main fossiliferous outcrops.

Depositional sequence 1 (DS1) encompasses a transgressive systems tract characterized by alluvial conglomerates and sandstones followed by deltaic to shallow-marine sandstones to siltstones and rarer shales (Figs. 1, 2). The alluvial and delta plain facies include trough cross-bedded, fining-upward lenses of clast-supported conglomerates and sandstones related to braided streams. The trough cross-bedded sets are bounded by low-angle, down-current dipping surfaces related to the frontal accretion of fluvial braid bars. The shallow-marine deposits are composed of fine- to medium-grained, well-sorted sandstone lenses displaying swaley and hummocky cross-bedding and rarer wave ripples associated with wave-dominated coastal areas.

Finally, the delta front and prodelta facies encompass coarsening- and thickening-upward packages of thin-bedded siltstones and rarer shales and fine- to very fine-grained, massive or climbing ripple sandstones (distal delta front to prodelta) overlain by massive, meter-scale sandstone lenses (proximal delta front).

A relatively deep-marine succession (DS2), mostly composed of high-density, channelized to unconfined turbidites (Apiúna Turbidite Complex) and fine-grained, slope to basinal facies, unconformably overlies the previous units and represents a succeeding lowstand systems tract. Turbidite channels comprise meter- to a few tens of meters-wide and several meters-thick lenses composed of matrix-supported conglomerates and/or very coarse- to coarse-grained, massive sandstones. The turbidite channel fill usually exhibits fining-upward trends and abundant rip-up clasts near their erosional bases and are surrounded by thin-bedded, fine-grained slope deposits. Slumped beds are rare. Unconfined, more distal turbidite deposits are tabular and composed of decimeter-scale beds of fine- to very fine-grained, massive to planar-bedded sandstones (turbidite lobe) and centimeter-scale couplets of fine- to very fine-grained sandstone and siltstone (lobe fringe). The transition between channelized and nonchannelized turbidite facies is gradual.

An erosional, subaerial unconformity highlighted by fluvial facies resting immediately above the slope strata of the previous depositional sequence delineates the base of the subsequent succession (DS3), which is mostly composed of deltaic to shallow-marine deposits that display features similar to those of DS1. The subsequent depositional sequence (DS4) repeats the previous sequence, including the presence of fluvial strata above a subaerial unconformity scoured into marine deposits of DS3. However, DS4 includes a larger proportion of fluvial and proximal, wave-influenced delta front sandstones than DS3. Above the fourth depositional sequence, a thick, strongly deformed, and partially inverted package (DS5) containing turbidite, delta front to prodelta, and alluvial strata occurs. However, its actual stratigraphic position is still uncertain. Whereas Rostirolla (1991), Fonseca (2004), and Guadagnin et al. (2010) describe it as the youngest sequence of the IB, Basei et al. (2011) suggest that this unit has been overthrusted onto the underlying units. The turbiditic, delta front to prodelta, and alluvial facies are similar to those described in more detail in DS1 and DS2.

The studied fossils and MISS were found in shallow- to relatively deep-marine strata (Figs. 1–3, and Supplementary Fig. 2), including the fine-grained, distal delta front facies of DS1 (e.g., outcrops AF236 and M12) and the upper slope facies (fine-grained, thin-bedded turbidites) close to the subaerial unconformity that delineates the DS2 upper boundary (e.g., outcrop A16). The fossils occur in millimetric rhythmites of clay, silt and fine-grained sand. Body fossils and/or microbial mats were not found in the deeper facies of DS2. No true palynomorphs were recovered from palynological macerations, but artifacts of particulate organic material were observed during the investigation (Supplementary Text 1).

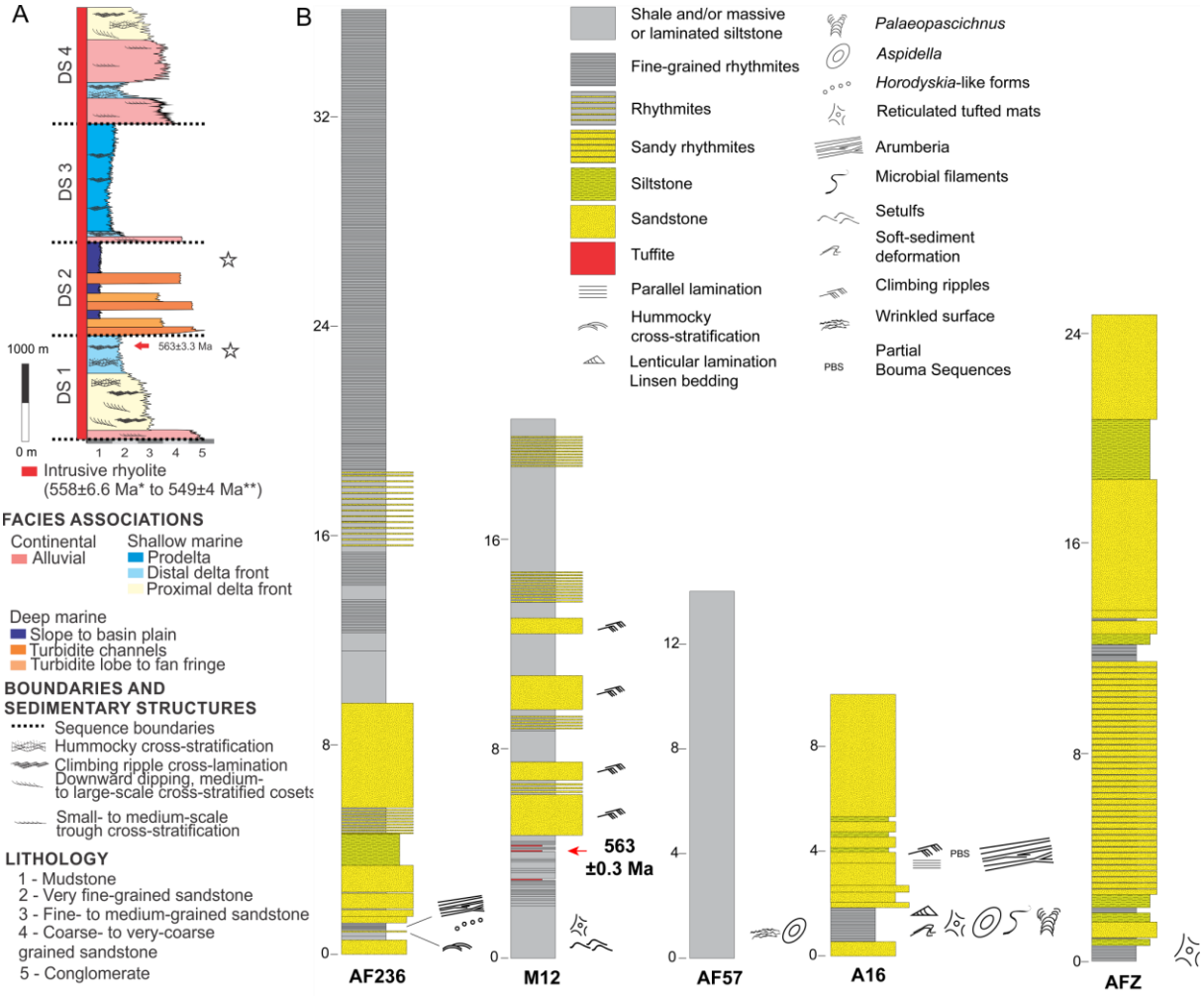


**Fig. 2**. A) Simplified composite column displaying depositional sequences DS1 to DS4, facies associations, related grain size trends, main sedimentary structures, estimated positions of fossil horizons (stars), and dated tuff layer (red arrow) (based on Fonseca (2004)); B) Profiles of the studied sections. *After Basei et al. (2011). **After Guadagnin et al. (2010).

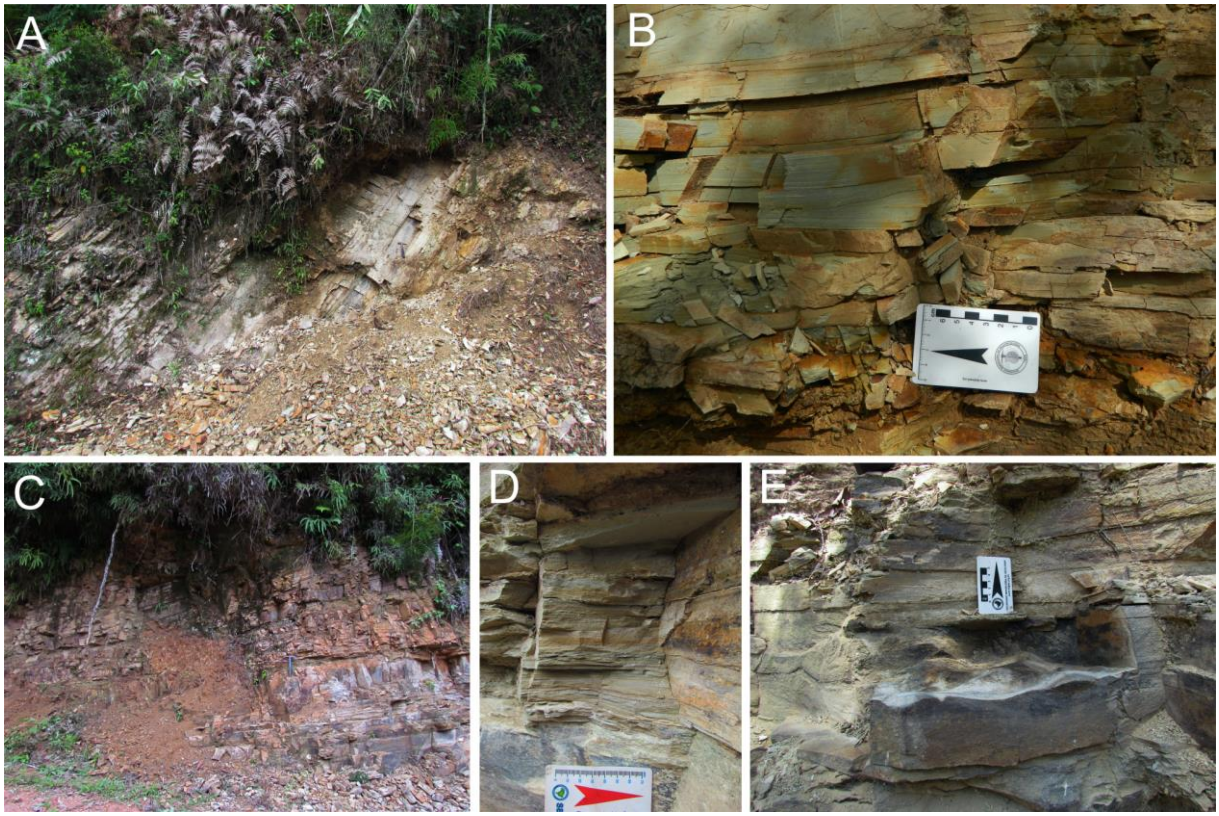


**Fig. 3.** Photographs of the main fossiliferous localities. A–B) Outcrop A16 (depositional sequences 2-3); B) Detail of the fossiliferous fine-grained rhythmites present in A16; C–E) Outcrop AF236 (depositional sequence 1); D) Detail of the fossiliferous horizon characterized by fine-sandstone/mudstone intercalations; E) Wave-rippled sandstone at the same locality.

## 3. Material and methods

### *3.1. Samples and localities*

We prospected approximately 234 outcrops (Supplementary Fig. 2, Supplementary Table) throughout the basin during field work, but the majority of samples were collected in the more prolific localities AF236, M12, A16, AF57, and AFZ (Figs. 1, 2). The samples were collected in situ, except for sample CAP/1A–558, which was found in the float. All hand samples, including body fossils and MISS (n = 295), analyzed here have been deposited in the “Coleção Arqueológica e Paleontológica” (CAP-549–582 and CAP-877–1019) at the Universidade Federal de São Carlos (Sorocaba, Brazil).

*3.2. Macroscopic and petrographic investigation*

Polished sections parallel and transverse to the bedding plane were made to examine the biological and sedimentary features under a SteREO Discovery V20 stereomicroscope coupled with an Axiocam camera at the Laboratório de Ecologia at the Universidade Federal de Mato Grosso do Sul. Thin sections were prepared at the Programa de Pós-Graduação em Geologia da Universidade do Vale do Rio dos Sinos (UNISINOS – São Leopoldo) and at the Setor de Laminação of the UNESP (Rio Claro). The thin sections were analyzed under a Leica microscope at the Instituto de Geociências of Universidade de São Paulo (IGc-USP).

*3.3. Scanning electron microscopy and μX-ray fluorescence*

Scanning electron microscopy (SEM) analyses were performed using Quanta 650FEG and FEI Inspect F50 microscopes at the Brazilian National Laboratory of Nanotechnology (LNNano/CNPEM), both in high-vacuum mode and with a current tension of 15 kV. Synchrotron radiation μX-ray fluorescence (SR-μXRF) mapping was performed at the Brazilian Synchrotron Light Laboratory (LNLS), and measurements were made using polychromatic excitation in microbeam mode and filtering with Fe foils. The FlyScan mode was used with 500 ms of count time per point. The data were later treated with PyMCA software.

*3.4. U-Pb geochronology*

Zircon grains were separated from a felsic tuff layer (sample T2A1M12; Figs. 1, 2) after crushing and milling using a jaw crusher and ring mill apparatus. Heavy and light minerals were separated using heavy liquids and a Frantz® magnetic separator after concentration of minerals by manual panning. Handpicked zircon crystals were mounted in an epoxy disc, ground and polished. Reflected light photomicrographs of samples were obtained, and images were produced using a scanning electron microscope for backscattered electron (BSE) and cathodoluminescence (CL) imaging. In situ laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) U-Pb zircon dating was carried out at the Isotope Geology Laboratory of Universidade Federal de Ouro Preto (Brazil) using a Photon-machines ArF excimer laser 193

coupled to a high-resolution sector field inductively coupled plasma mass spectrometer (HR-SF-ICP-MS, Element 2). A laser spot size of 30 µm was used, and data were acquired in peak jumping mode during a 20-s background measurement followed by a 20-s sample ablation. To evaluate the accuracy and precision of the laser ablation results, the zircon reference materials BB-1 (Santos et al., 2017), Plešovice (Sláma et al., 2008) and GJ-1 (Jackson et al., 2004) were also analyzed. The obtained ages agreed within the experimental errors: 563.8 ±3.2 Ma (n = 14) for BB-1, 601.3 ±2.8 Ma (n = 12) for GJ-1 and 338.4 ±2.2 Ma (n = 12) for Plešovice. The raw data were corrected for background signal, and laser-induced elemental fractional and instrumental mass discriminations were corrected by the reference zircon BB-1. The common Pb correction was based on the measured $^{204}$Pb composition (of the sample) following the model of Stacey and Kramers (Stacey and Kramers, 1975). The decay constant values used were from Jaffey et al. (1971). The data were corrected and reduced using the software Glitter (Van Actherbergh et al., 2001), and Isoplot-Ex (Ludwig, 2003) was used for age calculation. Uncertainty propagation was applied to the obtained data according to Horstwood et al. (2016).

## 4. Age

To constrain the age of the studied succession, U-Pb zircon dating was carried out on a tuff sample (Figs. 1, 2) by LA-ICP-MS. This rock is interlayered with distal delta front rhythmites in the upper portion of DS1, the basal unit of the IB (Figs. 1, 2). The tuff occurs near strata with MISS in outcrop M12 (Fig. 2). Approximately 70- to 250-µm-long zircon grains (n = 35) with prismatic and euhedral habits and sector zoning were extracted (Fig. 4A), following the work of (Corfu et al., 2003). Juvenile igneous zircons (31 of 35 dated grains) were recognized, yielding a concordant age of 563±3.3 Ma (95% confidence, MSWD=1.6) (Fig. 4B), which corresponds to the magmatic crystallization age of the tuff.

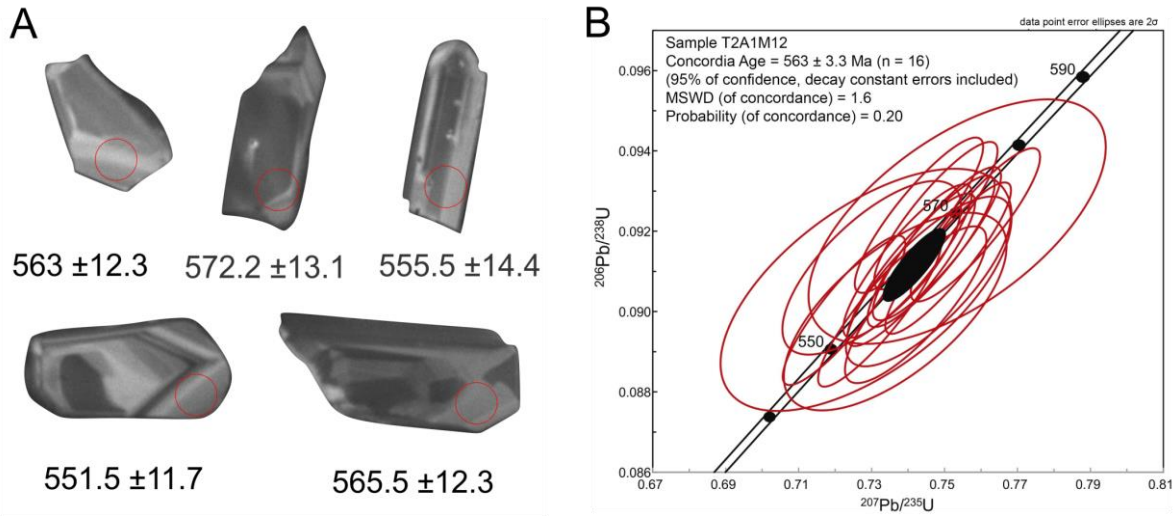


**Fig. 4.** A) Zircon morphologies obtained from the tuff investigated for radiometric U-Pb dating; B) Concordia diagram and concordia age obtained from the in situ LA-ICP-MS U-Pb zircon analyses.

These results broadly correlate this succession to the Avalon Assemblage (~570 – 557 Ma) (Schmitz, 2012; Noble et al., 2015; Pu et al., 2016) and mark the Itajaí Group as one of the earliest records of macroscopic life in Gondwana. The radiometric dating presented here is in accord with previously reported ages (Guadagnin et al., 2010), setting a minimal depositional age of 563± 3 Ma. Upper age limits given by the dating of the intrusive rhyolites that cross-cut the entire basin (ca. 558 Ma – 549 Ma; Basei et al. (2011), Guadagnin et al. (2010)) also corroborate an Avalonian age.

## 5. Body fossils

The body fossil assemblage includes *Palaeopascichnus*, *Aspidella*, *Nimbia,* and other problematic forms. These fossils were recovered from thin-bedded rhythmites related to upper slope (*Palaeopascichnus and Aspidella*) and distal delta front (*Aspidella* and *Nimbia*) depositional settings (Figs. 2, 3). The rhythmites are characterized by millimetric intercalations of clay and silt (Fig. 3B). The body fossils occur in association with abundant surface structures related to microbial mat growth in both slope and delta depositional environments. Additionally, neither body fossils nor MISS were found in the deeper facies (slope rise to basin plain).

*Palaeopascichnus* (n = 27) occurs as impressions comprising a series of straight to curved segments (i.e., chambers) and are abundantly preserved in some layers of mudstones in the thin-bedded rhythmite from outcrop A16 (Fig. 5). The chamber thickness varies from 0.1–0.3 mm, while the width varies from 0.3–1 mm. Some specimens show evidence of branching (Fig. 5A–B). The series width increases slightly in the direction of growth but diminishes after branching.

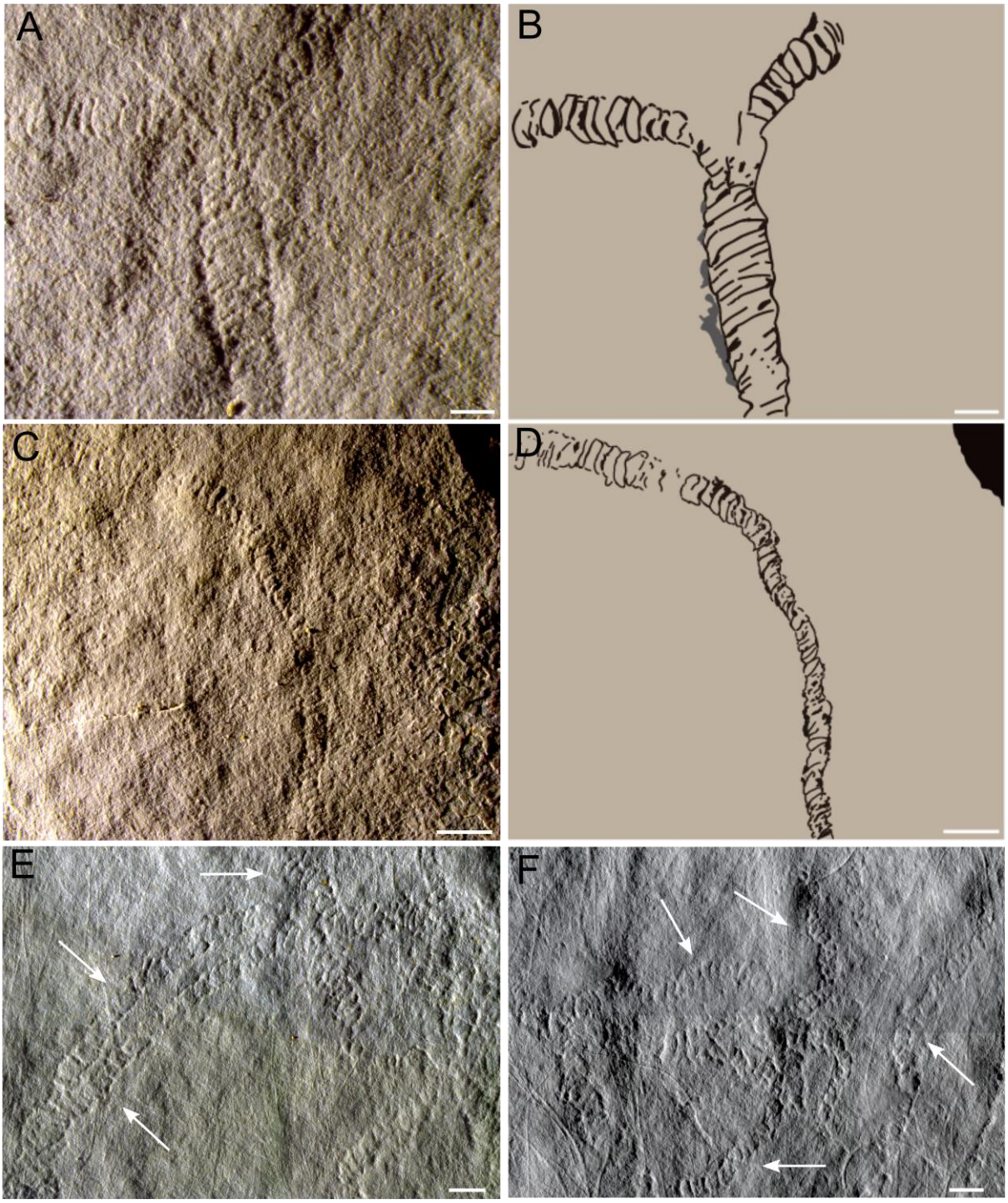

**Fig. 5**. *Palaeopascichnus* from the Itajaí Basin (CAP/1A–556). A) Specimen in positive epirelief showing bifurcation and a subsequent decrease in width; B) Interpretative drawing of A; C) Positive epirelief with *Palaeopascichnus* showing a gradual increase in width; D) Interpretative drawing of C. E-F) Several individuals occurring at the same level together with microbial filaments. Scales: 1 mm (A, B, E-F); 2 mm (C, D).

*Palaeopascichnus* is still considered to have unclear biological affinities, but it is well established as a body fossil (Antcliffe et al., 2011). Its chambered morphology has prompted previous comparisons with the modern group of giant protists Xenophyophora (Seilacher et al., 2003; Kolesnikov et al., 2018). Interestingly, this fossil is a long-ranging and, possibly, generalist organism (Kolesnikov et al., 2018), a common constituent of both the Avalon and White Sea Assemblages (Muscente et al., 2018), but also reported from deposits near the Ediacaran/Cambrian transition (Kolesnikov and Bobkov, 2019). Recent works have suggested that it may also represent one of the earliest skeletal (agglutinated) organisms (Kolesnikov et al., 2018). The presence of this fossil not only corroborates an Ediacaran age for the IB but also extends the paleobiogeographic range of this important taxon.

*Aspidella* specimens (n = 11) are preserved in negative to flat epirelief. These fossils mainly exhibit two morphotypes: convex and type morphs (following Gehling et al., 2000). The first morphotype is represented by convex ellipsoidal discs (n = 4) in positive hyporelief, with maximum diameters of ~10–14 mm and minimum diameters of ~9–12 mm. These forms present fine concave edges delimiting the convex disc. At the center, the disc shows a convex circular region (central boss) also delimited by a fine concave ring (Fig. 6A–B). One sample shows two conjoined specimens of the convex morph (Fig. 6C), while another presents an attached stalk-like structure (Fig. 6F–G). This morphotype was found within the thin-bedded rhythmite of outcrop A16 (upper slope setting). The type morphs (n = 4) were found in delta front and upper slope deposits and are preserved in negative epirelief; they are defined by an ellipsoidal disc (5–14 mm in diameter) with a concave external zone cut by radial lines that converge into a central ridge (Fig. 6D–E, H). Two of these specimens (Fig. 6H) were previously described as *Parvancorina* (Rosa, 2005). Additionally, two discs, similar to the intermediate forms described by Burzynski and Narbonne (2015), are

characterized by faint ellipsoidal impressions with maximum diameters of 15–22 mm and minimum diameters of 10–17 mm (e.g., Fig. 6I).

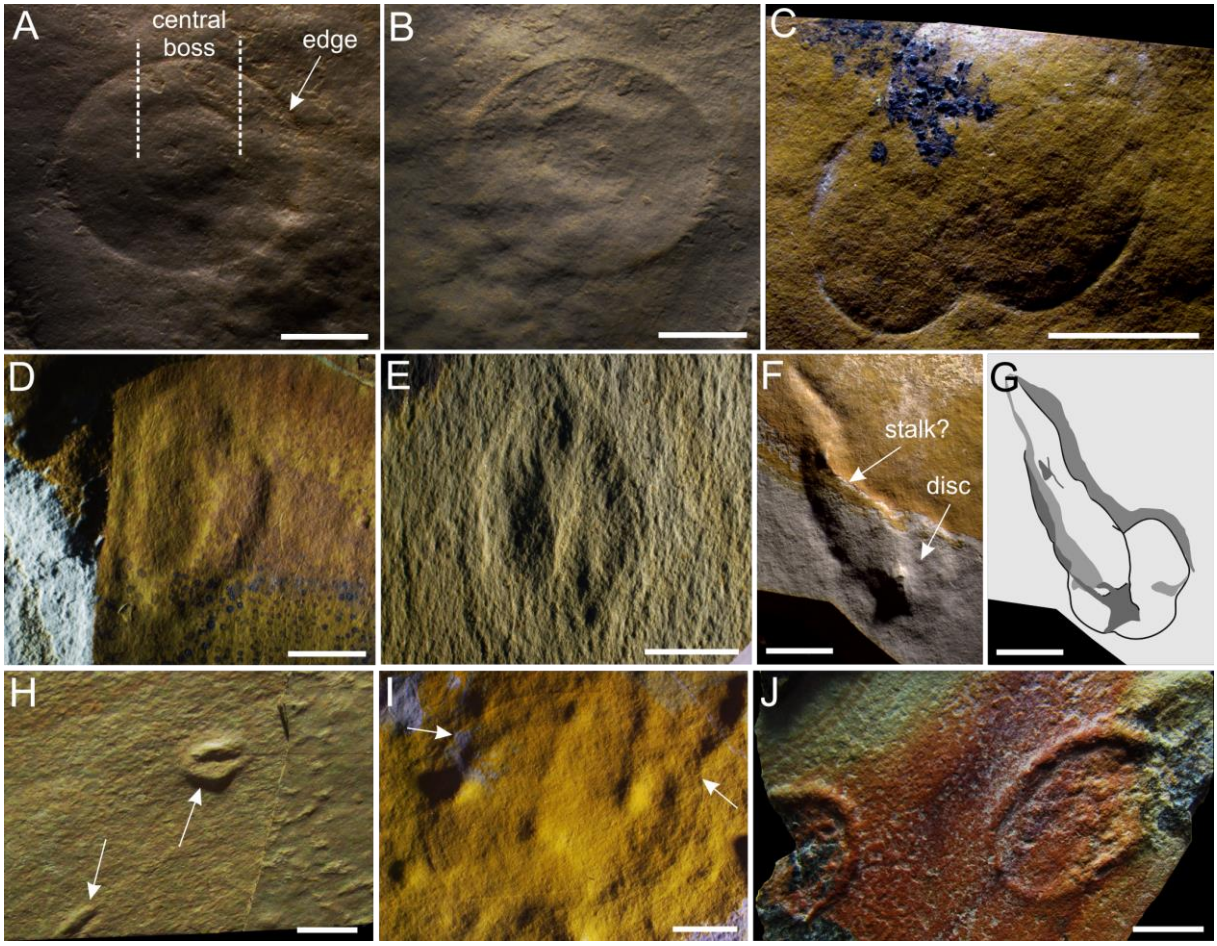


**Fig. 6**. Discoidal fossils from the Itajaí Basin. A) The convex morph of *Aspidella* in positive hyporelief, showing the central boss and concave edges (CAP/1A–549); B) counterpart of sample in (A). C) Conjoined specimens of the convex morph (CAP/1A–550); D–E) The type morph of *Aspidella* (arrows) from upper slope (D) and delta front deposits (E, H) (CAP/1A–878; CAP/1A–551); F) A disc (white arrow) in positive epirelief with possible attached stalk (black arrow) (CAP/1A–877); G) A schematic drawing of (F); H) Possible type morph of *Aspidella*, previously interpreted as *Parvancorina* (CAP/1A–552); I) Faint impression of a discoidal morphology (CAP/1A–555); J) *Nimbia* specimens from distal delta front deposits (CAP/1A–553). Scales: 5 mm (A–F, G, I); 10 mm (H, J, K).

Discoidal forms are one of the most common morphotaxa found in Ediacaran rocks, but there are also reports of similar fossils in rocks of different ages (Nagovitsin

et al., 2008; Burzynski et al., 2020). Although usually regarded as the holdfasts of Ediacaran fronds (Gehling et al., 2000; Tarhan et al., 2015), other interpretations, including microbial colonies and fluid escape structures, have been made for some occurrences (Grazhdankin and Gerdes, 2007; Menon et al., 2016). Thus, studies dealing with discoidal impressions should evaluate these different possibilities. However, distinguishing the origin of these structures can be difficult, and several occurrences may still be considered problematic (e.g., Inglez et al., 2019).

In the IB, at least for the *Aspidella* morphs, our results showed that these fossils could be related to the basal portions of complex macroscopic forms (e.g., frondose organisms). For instance, one specimen preserved in positive epirelief showed an attached stalk-like structure (Fig. 6F–G) that could represent the stalk of a macroscopic frond-like organism. This structure greatly differs from the filamentous fossils described below, both by its larger size and tapered nature. Tool marks are an unlikely origin, since the observed feature is preserved in positive epirelief. Additionally, load casts were not seen in these beds, and their usual mode of occurrence (positive features on the sole of beds) differs from our case. Alternatively, another possibility is the formation by rolled-up mats, which could explain the positive epirelief of the structure. However, it is intriguing that this form appears to be associated with a disc.

Polished sections of *Aspidella* showed no evidence for fluid escape structures (Fig. 7). In some samples, convolute laminations are present, but an undisrupted layer of fine-grained sand just below the fossil suggests that the soft-sediment deformation had no influence on the morphology of the disc (Fig. 7C–D). Thus, it is unlikely that these forms represent fluid/gas escape features or abiotic geologic features. It is also questionable whether the fossils could represent microbial colonies, since they lack several concentric rings, sharp radially arranged furrows and filaments, all of which have been suggested to be evidence for a microbial colony origin (Grazhdankin and Gerdes, 2007).

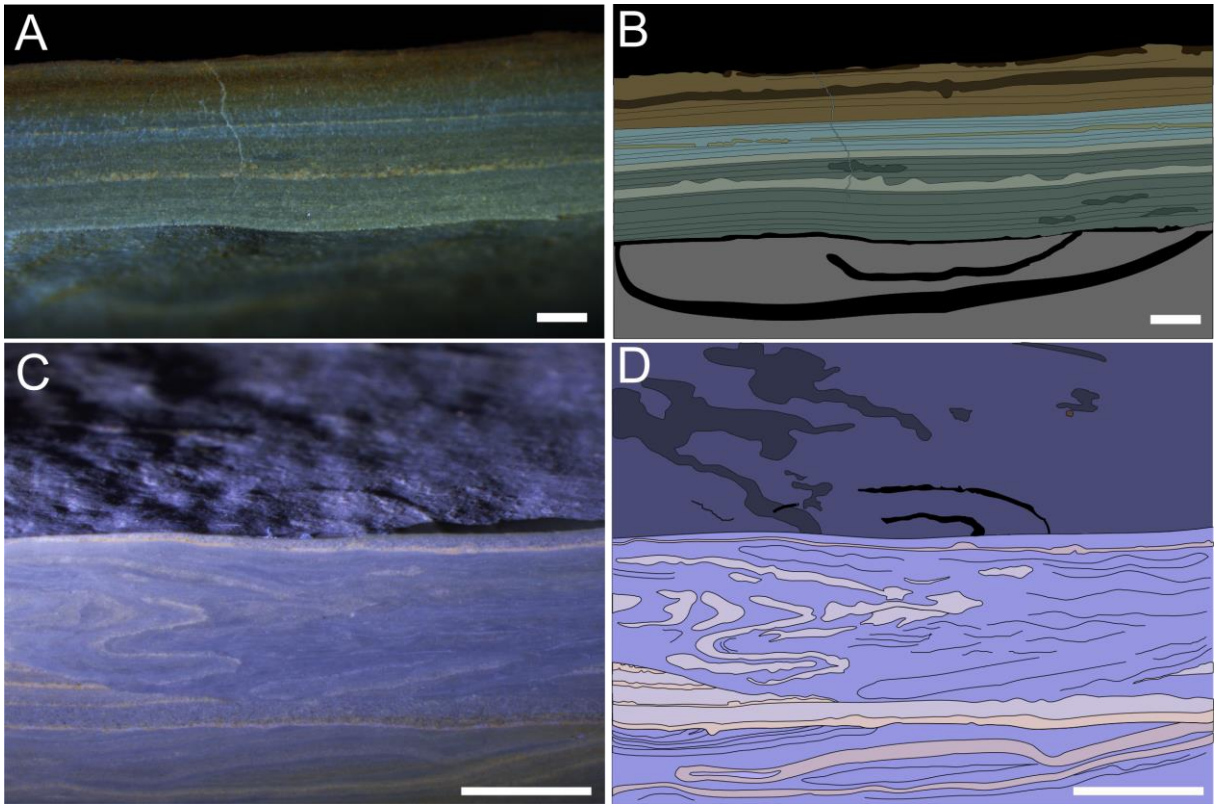


**Fig. 7.** Polished sections of *Aspidella*. A) Vertical section through positive hyporelief showing undisturbed laminations above the specimen; B) Schematic drawing of A; C) Section of epirelief demonstrating an undisturbed sandy layer below the specimen; D) Schematic drawing of C. Scales: 1 mm (A, B), 5 mm (C, D).

In contrast to *Aspidella*, *Nimbia* (n = 18) is found only in the distal delta front deposits (outcrop AF236). These discoidal impressions are characterized by ellipsoidal rings in positive epirelief (Fig. 6J). The discs present major axes of 24–30 mm and minor axes of 16–19 mm, with annular ring widths of 1.5–3 mm. The annular ring surrounds a nearly flat surface, which presents only faint circular protrusions (Fig. 6J). One sample separated for thin sectioning did not exhibit fluid escape features or wavy-crinkly lamination.

Recent work (Liu et al., 2013a) has suggested a microbial origin for *Nimbia*, an acceptable interpretation based on its similarity to modern ring structures constructed by the cyanobacteria *Lyngbya aestuarii* at Laguna Mormona (compare our Fig. 6J to Fig. 4E of Horodyski (1977)).

## 6. Three-dimensional microbial mats and MISS

### *6.1. Reticulated tufted mats*

Most of the occurrences of microbially related structures represent reticulated tufted mats, which consist of millimetric pinnacles (or cones) connected by ridges (Fig. 8A–B). The centers of the pinnacles are circular to elliptical in horizontal sections (Fig. 8B, D), with a mean width of 1.7 mm (n = 37). The ridges present a mean width of 0.4 mm (n = 37) and are slightly larger in the proximities of the pinnacles and gradually decrease in width farther from them. These well-preserved tufted mats often co-occur with micrometric microbial filaments (Fig. 8E–F).

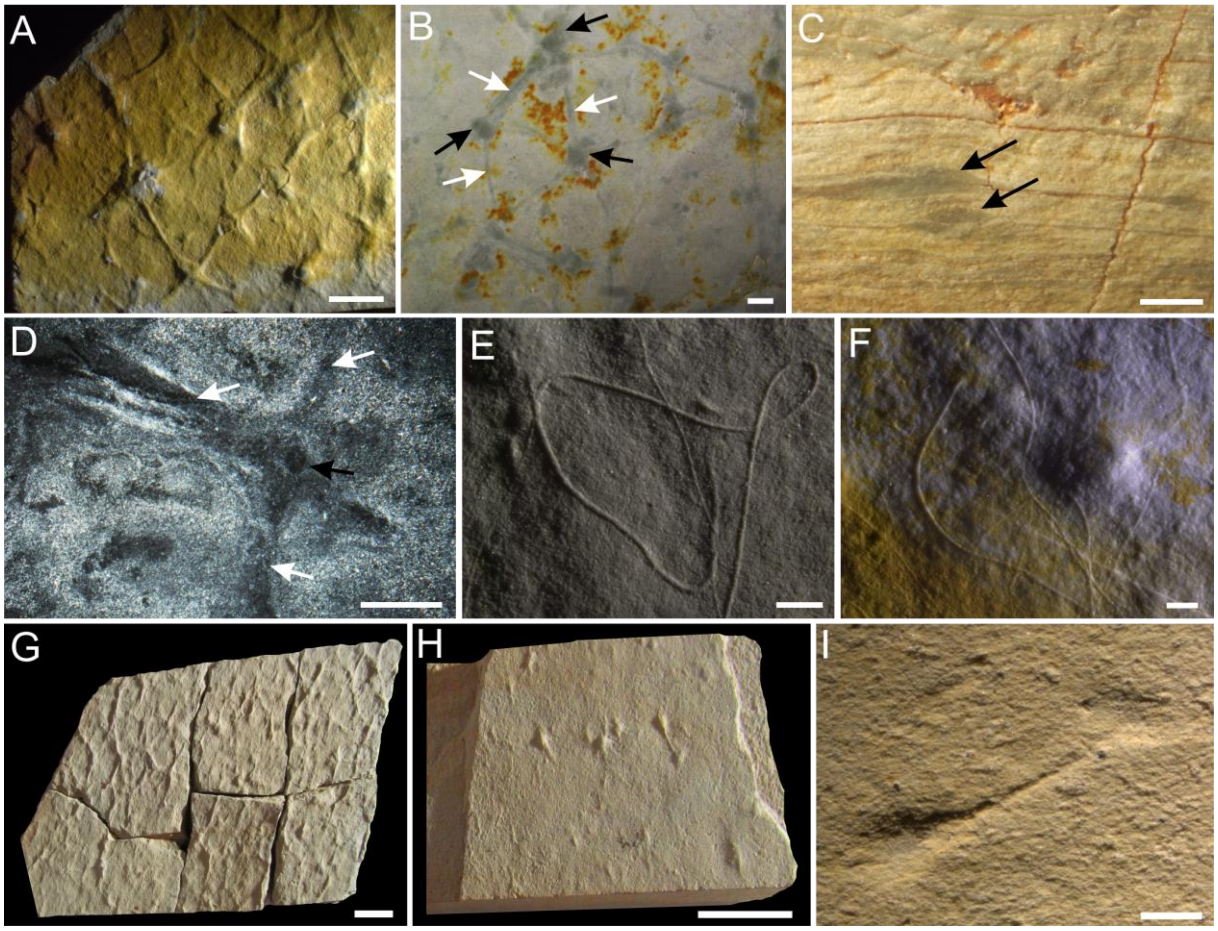


**Fig. 8**. Hand samples and thin sections of microbial tufted mats. A) Bedding plane views of three-dimensional microbial tufts (CAP/1A–559); B) Hand sample polished parallel to the bedding plane, revealing the preservation of the microbial mats by an argillaceous material darker than the surrounding rock (CAP/1F–03). Note the sectioned pinnacles (black arrows) and the ridges connecting them (white arrows) (CAP/1F–03); C) Transverse section of a hand sample, indicating the presence of

small elevations that correspond to the cones of the mat (arrows) (CAP/1A–560); D) Thin sections made parallel to the bedding plane, highlighting the three-dimensional morphology of the microbial mats, with ridges (white arrows) and pinnacles (black arrows) (CAP/1F–03). (E–F) Micrometric filaments often found associated with the first stages of formation of the tufted mats (CAP/1A–561; CAP/1A–555). (G–I) Reticulated tufts preserved as simple surface morphologies (CAP/1A–570; CAP/1A–571). Scales: 5 mm (A); 1 mm (B–C, E–F, I); 0.5 mm (D); 10 mm (G, H)

This type of microbial mat is abundant in the thin-bedded rhythmites (upper slope), where *Aspidella* and *Palaeopascichnus* also occur (outcrop A16), as well as in the distal delta front deposits. Specifically, in the upper slope facies, these fossilized tufted mats are three-dimensionally preserved, a feature clearly evident in polished and thin sections (Fig. 8B, D). The presence of Si, Al, K, Fe and Ti demonstrated by SR-μXRF point analysis (Supplementary Fig. 3) points to an aluminosilicate composition with associated titanium phases. In contrast, the tufted morphologies in the distal delta front deposits (Fig. 8G–I) are preserved only as impressions and are thus similar to the typical preservation of MISS.

Samples also show different degrees of interconnection of the centers. Small domes with incipient connections (Fig. 9A–B) gradually transition to more reticulated and interconnected mats (Fig. 10).

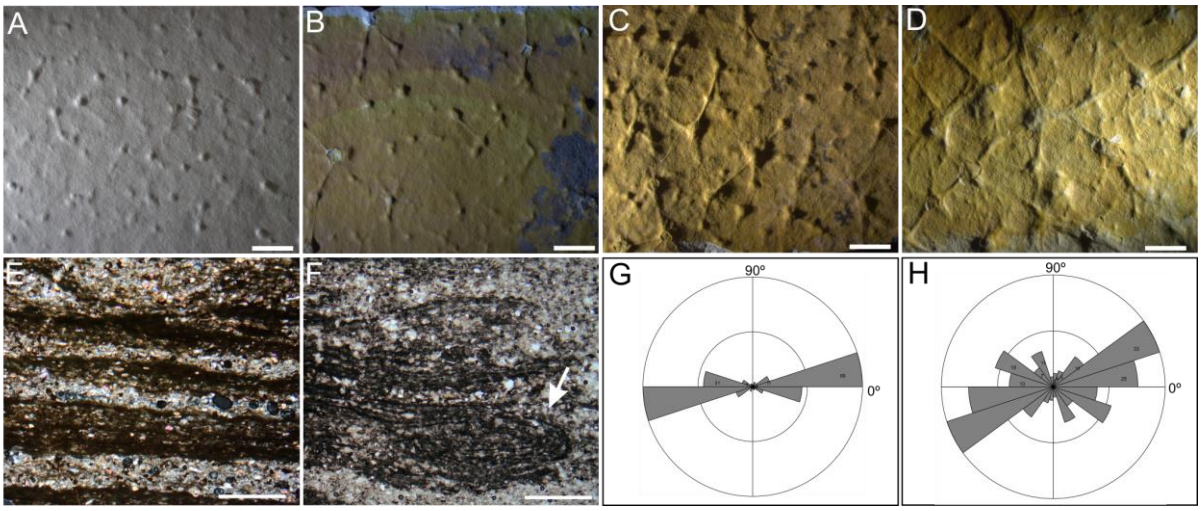


**Fig. 9.** A–B) Different stages of formation of tufted microbial mats (CAP/1A–567; CAP/1A–568; CAP/1A–569; CAP/1A–559). E–F) Wavy-crinkly lamination with abundant floating grains (CAP/1F–08), and evidence of soft deformation (B) (CAP/1F–

09); G) Orientation of grains inside microbial laminae (n = 125); H) Orientation of grains in the siltstone-sandstone layers (n = 130). Scales: 5 mm. (A–E); 1 mm (E–F).

Wavy-crinkly laminae with evidence of cohesive behavior and disrupted laminations are also found associated with these tufts in thin sections (Fig. 9E–F). Horizontally oriented floating grains are observed within the wavy-crinkly laminations (Fig. 9G–H).

The three-dimensional preservation of the Itajaí Group reticulated mats has yielded good retention of the original morphology, apparently showing different degrees of developmental growth, from isolated domes through more interconnected samples to a fully established reticulated tufted mat (Fig. 9). Similar formative processes have been observed in recent photosynthetic reticulated mats (Shepard and Sumner, 2010). For instance, studies have associated the genesis of tufts and reticulated patterns with gradients in oxygen (Sim et al., 2012) and undirected filament gliding and collision, followed by their alignment and clumping (Shepard and Sumner, 2010). Conspicuously, the afore mentioned processes of the origin and development of tufted mats (Walter et al., 1972, 1976; Flannery and Walter, 2012) may also account for the morphologies recorded in the Itajaí biota (Figs. 8–9). Additionally, it is worth noting that IB tufts are very similar to modern microbial tufts (see Fig. 2-1-4 in Schieber et al. (2007)) constructed by filamentous cyanobacteria, such as *Lyngbya aestuarii* (Horodyski, 1977) and *Microcoleus chthonoplastes* (Schieber et al., 2007).

Likely due to the peculiar three-dimensional preservation (Fig. 8) of the tufted mats, these morphologies were first thought to represent the preserved remains of *Chancelloria* (Da Rosa et al., 1997; Leipnitz et al., 1997; Paim et al., 1997). However, the resemblance is only superficial since the IB structures do not present any boundaries related to a body outline, and the “sclerites” (i.e., pinnacles and ridges) lack the regular morphology observed in true *Chancelloria* sclerites. In contrast, these features cover the whole bedding plane surface and are irregular in the number of ridges that depart from the pinnacle.

Some variations in the morphology of these tufted mats can generate a false dumbbell appearance, which led to the interpretation of these features as the ichnogenus *Diplocraterion* (Netto and Rosa, 1997). However, we observed that these

structures are characterized by millimetric domes interconnected by more than two strands (Fig. 10) and are similar in size to the reticulated microbial mats described above. Micro-computed tomography (µCT) analysis demonstrated no deformation in the laminations beneath the structures (Fig. 10C). This absence of *spreiten* morphologies in microtomographic investigations (Fig. 10C), combined with the interconnection of more than two spherical structures (Fig. 10D–E), suggests a network of interconnected tuft pinnacles and not a true dumbbell morphology related to a vertical shift in sediment.

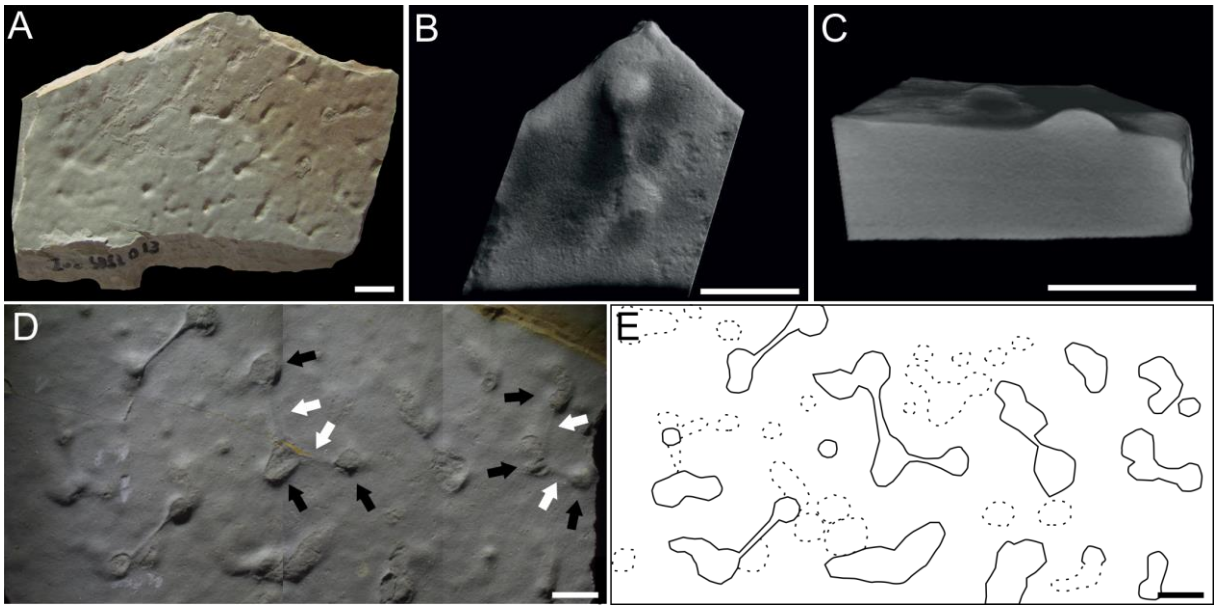


**Fig. 10**. Tufted microbial mats resembling dumbbell morphologies (CAP/1A–579). A) Hand sample with interconnected dumbbell forms; B) µCT image of the surface of a sample with a dumbbell shape; C) Transverse section of the µCT reconstruction; D) Hand sample demonstrating the presence of more than two spherical structures (black arrows) interconnected by strands (white arrows); E) Schematic representation of D. Scales: 10 mm (A); 5 mm (B–E).

The filamentous impressions occasionally occurring associated with the reticulated mats were also previously interpreted as trace fossils (i.e., *Helminthoidichnites*; Netto, 2012). Instead, our observations suggest that these fossils represent exquisitely preserved microbial filaments. Their body fossil nature is evident by the overlap of individuals (Fig. 8E–F), instead of a cross-cutting interaction that would be expected in horizontal trace fossils. For the same reason, these filaments are

unlikely to be tectographs (e.g., Seilacher et al., 2000). Therefore, no strong evidence indicates the presence of ichnofossils in the IB – a situation that is similar to other deposits with analogous ages (but see references Liu et al., 2010 and Liu et al., 2015 for putative trace fossils in the Avalonian biota). Abundant and undisputable trace fossils appear later in the White Sea Assemblage (Droser et al., 2006).

### *6.2. Arumberia-type microbial mats*

Another type of 3-D preservation of microbial mats in the Itajaí Group is Arumberia (Fig. 13). This fossil consists of an almost parallel series of filamentous structures arranged horizontally on the bedding planes (Fig. 11A–C). Lateral connections are observed. The width of the filaments can vary along stratigraphic levels, but they occur mainly in two size ranges: 0.5–0.8 mm (mean = 0.52, n = 16) and 0.9–3 mm (mean = 1.6, n = 40). Extremities are not observed, but dichotomous ramifications of the filaments are more abundant in the smaller type than in the larger one. Most of the structures are three-dimensionally preserved in a manner similar to that described above for the reticulated tufts (Fig. 11D), and thin sections indicate that the filaments exhibit ellipsoidal or domal outlines with convex tops in cross-section (Fig. 11D). The base of the mats presents a more horizontal surface than the top, apparently following the bedding plane (Fig. 11D). Arumberia appears both in the distal delta front and upper slope settings. Orientation measurements of Arumberia crests in the first depositional setting show a preferential direction (Supplementary Fig. 4) that is comparable to previously reported paleocurrent readings for the same depositional sequence (Fonseca, 2004).

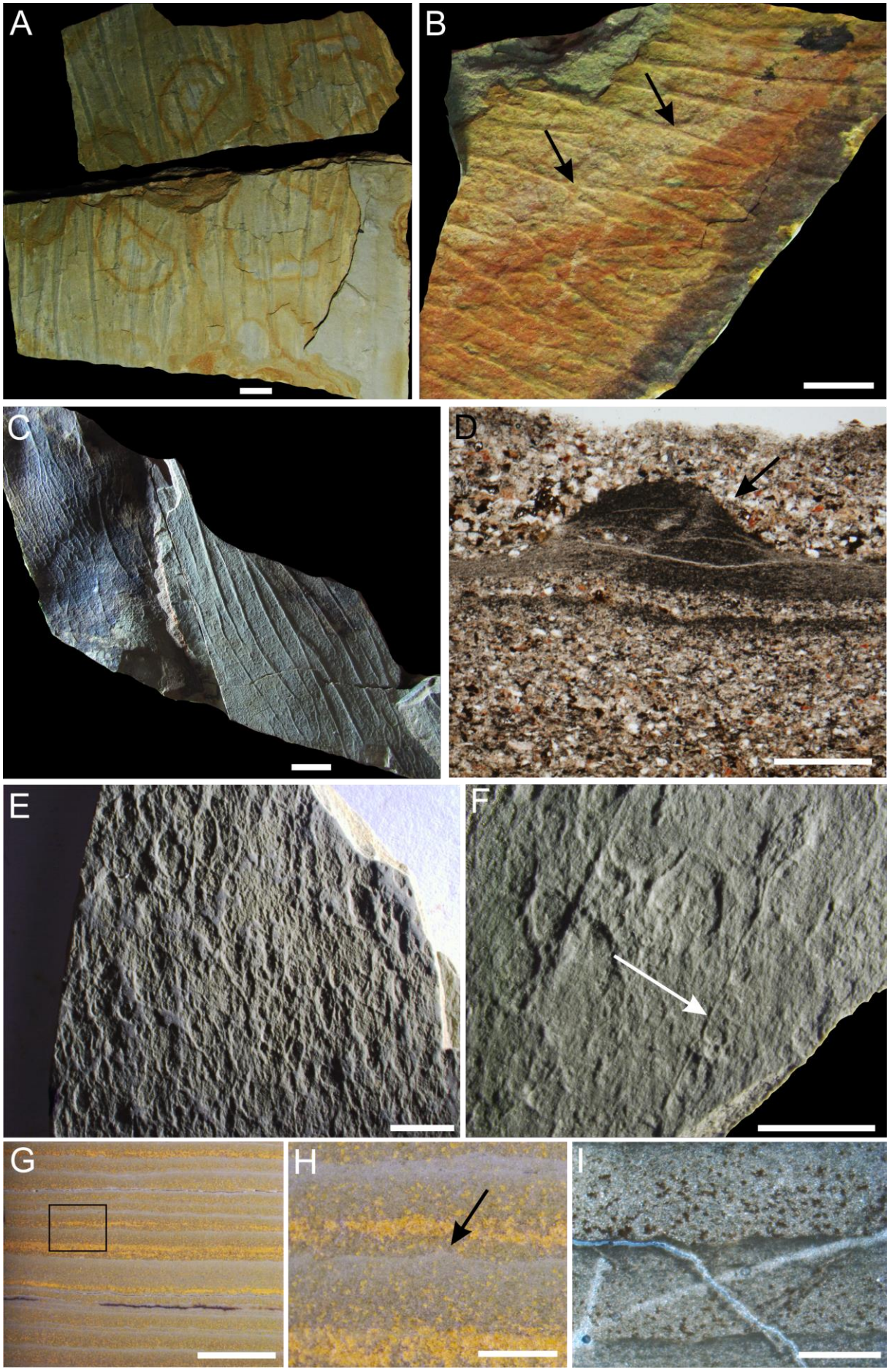
A
B
C
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**Fig. 11**. Arumberia mats and simple wrinkled surfaces. A–C) 3-D preserved specimens on a bedding plane (as viewed from above) exhibiting abundant linear crests and common ramifications (arrows) (CAP/1A–563; CAP/1A–564; CAP/1A–566); D) Thin section (in transmitted light) of a 3-D preserved Arumberia in transverse sections showing the domal outline of the crest and the lateral connections (CAP/1F–05). E–F) Hand samples with wrinkles on top of the beds (CAP/1A–572; CAP/1A–575). The white arrow highlights a filamentous structure; G) Transverse section and polished surface of a hand sample with wrinkles (CAP/1A–576); H) Enlargement of the rectangle in (G), presenting a ridge in cross-section (arrow); I) Thin section of wrinkles demonstrating little variation in grain size (mostly clay and fine silt) between the laminae. Scales: 10 mm (A–C); 0.5 mm (D); 5 mm (E–G); 1 mm (H–I).

The biological affinity of Arumberia is still considered controversial (Davies et al., 2016) since it has been interpreted as a body fossil (Glaessner and Walter, 1975), an abiogenic structure resulting from turbid flow (Brasier, 1979), and the product of scouring currents on a microbial mat surface (McIlroy and Walter, 1997). Our three-dimensional specimens preserved by aluminosilicates presenting laterally continuous connections in perpendicular sections corroborate a mat morphology, thus supporting the third interpretation.

Remarkably, the similar orientations between the crests of Arumberia (Supplementary Fig. 4) and sedimentary structures (Fonseca, 2004) in the delta front deposits of the IB indicate that currents indeed could have played a role in the formation of this peculiar morphology. Additionally, its occurrence in the delta front deposits suggests that this structure most likely represents the growth of photosynthetic microbial communities. Arumberia-like mats have recently been observed in modern photosynthetic mats (Kolesnikov et al., 2017).

### *6.3. Simple wrinkled surfaces*

Simple wrinkles are the most common surface structures in the delta front and prodelta sediments of the IB (Fig. 11E–I). They are defined by simple reticulated textures formed by a network of intertwined convex ridges (0.2 – 1.8 mm). In contrast to the tufts, these wrinkles do not present either pinnacles or a more organized reticulated fabric. Some samples display rare associated submillimetric filaments (Fig.

11F). The hyporelief of the reticulated structures is characterized by convex bulbous polygons and narrow concave depressions, similar to the so-called elephant-skin texture. In transverse sections and thin sections, the wrinkles appear as crinkly laminations alternating with iron oxide-rich laminae (Fig. 11G–I). There are no significant changes in the grain size between the laminations.

These wrinkles are interpreted to represent surface sedimentary features related to mat growth, as evidenced by the crinkly laminae in thin sections and their resemblance to biolaminites in vertical sections (Fig. 11G–I). The origin by loading can be ruled out by the homogeneous grain size (mostly clay to fine-grained silt) at the interfaces where the wrinkles occur (Fig. 11I). Additionally, their association with putative microbial filaments (Fig. 11F) further supports a microbial mat interpretation. These simple wrinkles differ from the reticulated tufts by their more irregular arrangement and lack of pinnacles. It is unlikely that they represent a taphonomic variation of the latter because gradational morphologies were not observed and the presence of fine structures such as filaments suggests that some surfaces were relatively well preserved.

### *6.4. Small discoidal structures*

Simple and abundant discoidal protrusions were observed on top of the beds (positive epirelief) in outcrop AF236 and near the Arumberia level, although the two are seldom seen in the same bedding plane. These ‘pimples’ exhibit circular to ellipsoidal outlines, millimetric diameters (1.2 – 3.7 mm), and heights of ca. 0.5 mm (Fig. 12). Some specimens show circular depressions in the center of the pimple (Fig. 12D), which is due to unequal partitioning of part and counterpart, leaving portions of the structure on the hyporelief (Fig. 12F). The counterparts (sole of the beds) are characterized by negative hyporelief circular impressions (Fig. 12F–G, K). Transverse sections of hand samples show no pipe or fluid escape structures, but some pimples present higher concentrations of clay minerals in the upper portion of the structure (Fig. 12H–I) or even in the whole pimple (Fig. 12I).

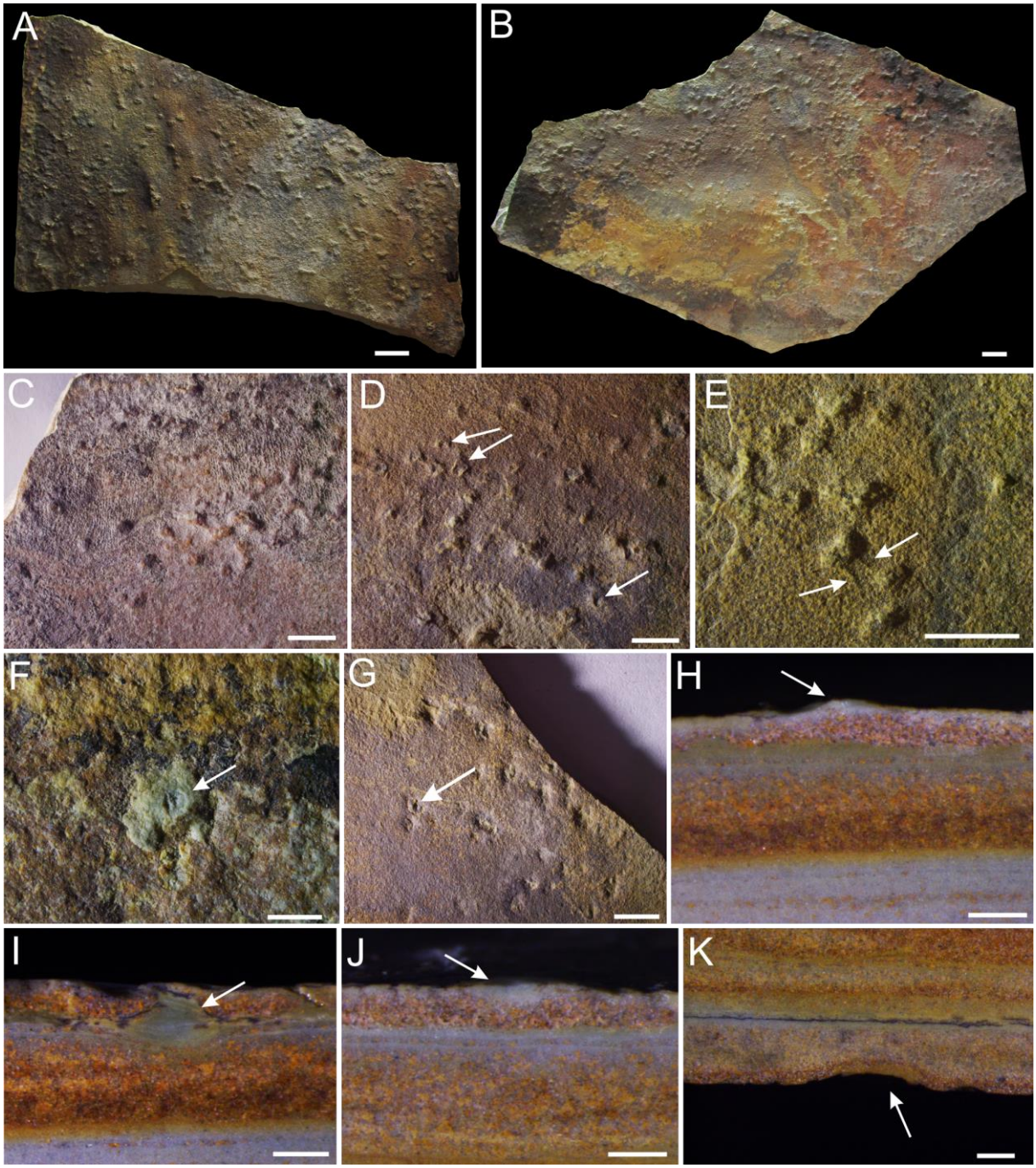



**Fig. 12.** Pimples from the Itajaí Basin. A**–**B) Hand samples with a profusion of specimens on top of the beds (positive epirelief) (CAP/1A–577; CAP/1A–578); C**–**E) Close-up of the structures in epirelief, showing depressions at the centers of some individuals (white arrows in D) and connecting ridges (white arrows in E) (CAP/1A–578); F) Portion of a pimple left on the bottom of the bed (CAP/1A–578); G) Hyporelief with small pits, corresponding to the counterpart of the pimple (CAP/1A–578). The white arrow marks the presence of portions of the pimple left behind after separation of the sample; H**–**J) Transverse sections of the pimples in epirelief (CAP/1A–577). Note

the concentrations of argillaceous white material (white arrows). K. Transverse section of hyporelief (CAP/1A–577). Scales: 10 mm (A, B); 5 mm (C–E, G); 0.5 mm (F); 1 mm (H–K).

Simple and small discoidal structures are commonly observed in Meso-Neoproterozoic deposits (Mcilroy et al., 2005; Callow et al., 2011; Menon et al., 2016), and a variety of taxonomic names (e.g., *Beltanelliformis brunsae*, *B. minutae*, *Intrites punctatus*, *Medusinites* aff. *asteroides*, and *Rameshia rampurensis*; see Mcilroy et al. 2005 and Kumar and Pandey 2008) or descriptive terms (e.g., small discoidal forms, mounds, domes, and pimples; see Menon et al. 2016 and Callow et al. 2011) have been used to encompass morphological variations of these forms. Thus, following the same pattern as for other discoidal impressions, controversies arise regarding their biological affinities. Recent works have presented strong evidence that some are the result of fluid escape and subordinate load structures, which occurred in a substrate dominated by microbial mats (Menon et al., 2016). In terms of morphology and size, IB small discs are more similar to the pimples reported by Menon et al. (2016) and Callow et al. (2011).

However, regarding the IB pimples, we did not observe pipes or disturbed laminations (Fig. 12H–K). Furthermore, they are preserved in positive epirelief, similar to the 1 Ga. pimples reported by Callow et al. (2011) but unlike the Ediacaran negative epirelief pimples of Menon et al. (2016). Strand connections observed between some IB specimens also argue against a fluid escape origin, suggesting similarities between the pimples and the stages of formation of microbial tufted mats. It is interesting to note that Arumberia is commonly reported to co-occur with small round impressions in positive epirelief (e.g., Bland, 1984; Callow et al., 2011; Kumar and Ahmad, 2014; Kumar and Pandey, 2008), as is the case in the IB. Therefore, we suggest that these forms represent different stages of formation of microbial surfaces and/or microbially bound surfaces under different energetic systems.

## 7. Problematic forms

### *7.1. Linearly arranged pits*

These structures are characterized by impressions of serially arranged pits on the sole of the bed (negative hyporelief) (Fig. 13A–B). Each pit has a subrounded outline, and the diameter varies between 1 and 1.5 mm (n = 10). The distances between the centroids of each pit vary between 2.4 and 4.7 mm (n = 8). The specimen in Fig. 13A shows faint strings connecting the beads. One sample (CAP/1A-558) exhibits specimens preserved in three dimensions, possibly by iron oxides, as indicated by the higher intensities of Fe in the fossils than in the host matrix (Fig. 13D–G). In addition, there is displacement of sediment around one of the beads (Fig. 13C), suggesting formation prior to the lithification of the rock.

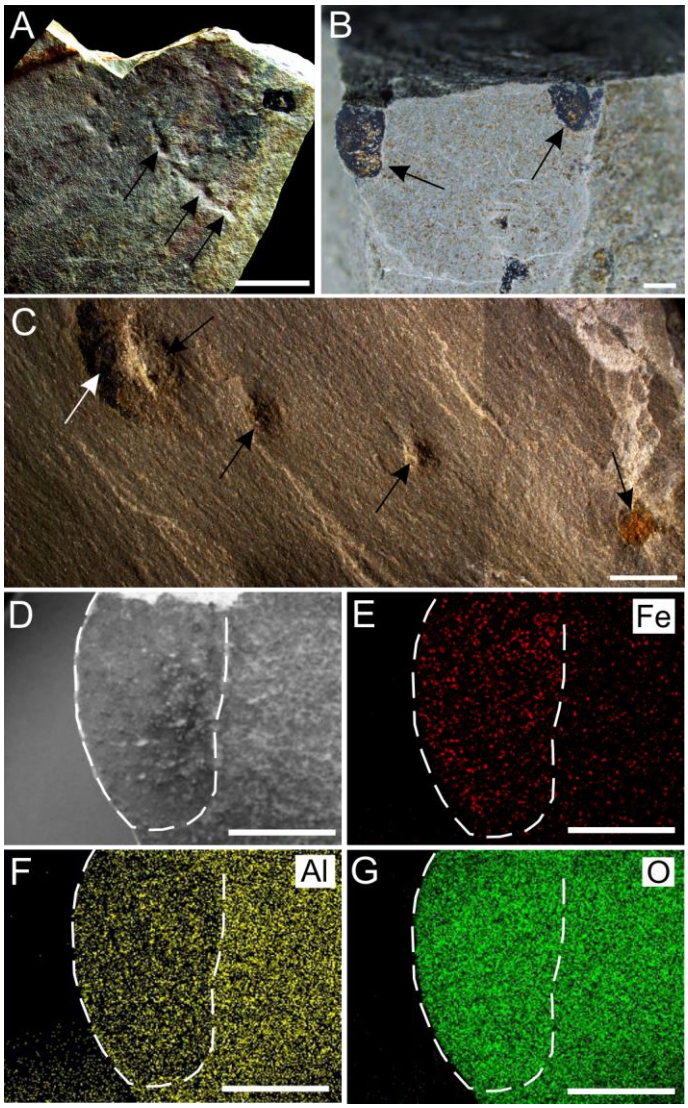



**Fig. 13**. Hand samples and energy-dispersive X-ray spectroscopy (EDS) maps of linearly arranged beads. (A) An impression of negative hyporelief of serially arranged pits (arrows) from the delta front deposits (CAP/1A–553). Note the presence of possible strings in the specimen; B–C) 3-D preservation of beads in transverse section

(C) and in bedding plane view (D) (CAP/1A–558); D–G) Electron image (D) and EDS maps (E–G) of the specimen in (B). Scales: 10 mm (A); 1 mm (B, D–G); 5 mm (C).

In contrast to other body fossils described here, the specimens described as linearly arranged pits are less discernable morphologically. However, their arrangement and the presence of strings connecting some of the circular structures (Fig. 13A) favor a biogenic origin. The morphology and size resemble those observed in the fossil *Horodyskia*. This taxon was defined as impressions of strings of beads, sometimes presenting connecting strands (Grey and Williams, 1990; Calver et al., 2010). However, *Horodyskia* has mostly been reported from Mesoproterozoic deposits, and Ediacaran occurrences, such as those in China (Shen et al., 2007; Dong et al., 2008) and India (Mathur and Srivastava, 2004), are considered controversial (Calver et al., 2010).

Alternatively, these linearly arranged pits could represent a different taphomorph of the pimples, in which bottom currents produced a linear arrangement of the structures. This could be the case for the sample illustrated in Fig. 13A but seems more unlikely for the 3-D forms considering their morphologies. In this sense, these two types of structures may exhibit distinct origins. The preservation by iron oxide also suggests that pyritization may have been the pathway for three-dimensional preservation. Nevertheless, due to an insufficient number of samples and poor preservation, no further interpretations about these structures can be made at present.

### *7.2. Stellate discs*

Millimetric discs with submillimetric radial lines (Fig. 14) are present in two different preservation modes: as low relief molds and as flat yellow discs. In the first type, we observed displacement of sediment near the border of one of the discs. Stereomicroscopy and SEM investigations of the yellow discs showed the presence of cubic pseudomorphs of pyrite (Fig. 14G) and submicrometric star-shaped crystals, respectively (Fig. 15). EDS mapping demonstrated that the intensities of Fe are higher in the discoidal form than in the host rock (Fig. 14J–N).

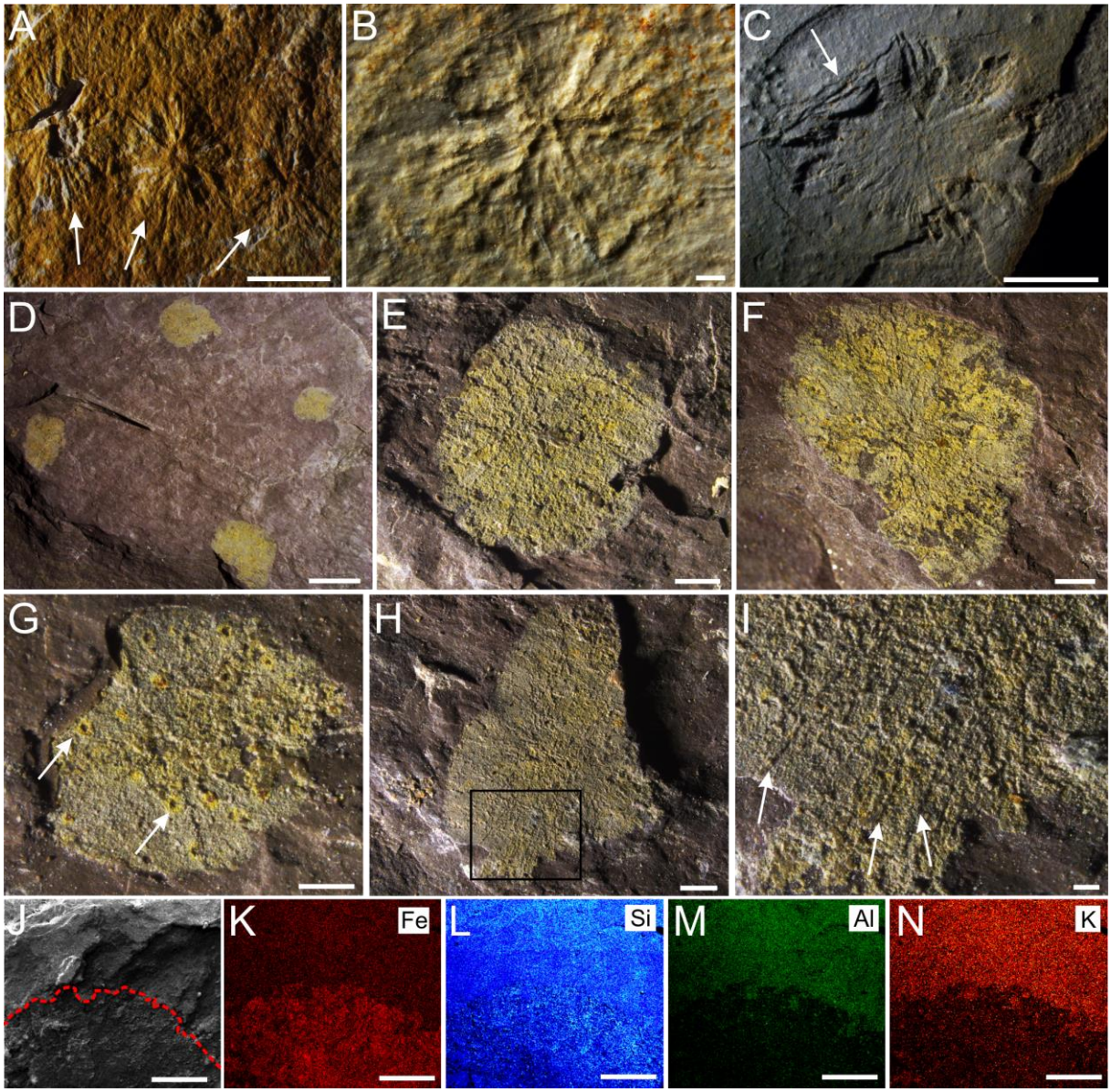



**Fig. 14**. Enigmatic discs from the IB. A. Three juxtaposed specimens of discs with radial lines (positive hyporelief) (CAP/1A–580). B. Radial disc with almost flat relief (CAP/1A–581). C. Irregular outline of one radial disc, with evidence of sediment displacement (white arrows) (CAP/1A–582). D–I. Flat, yellow discs with scarce radial crests (white arrows in I) and cubic crystals (white arrows in G) (CAP/1A–583). J–N) Electron image and EDS maps of a yellow disc (below the red line) (CAP/1A–584). Scales: 1 mm (B, E, F, H); 5 mm (A, C–D); 0.5 mm (G); 0.2 mm (I); 0.4 mm (J–N).

Stellate discs similar to those in Fig. 14A–C were putatively interpreted as body fossils of the Cambrian taxon *Choia* (see Becker-Kerber et al., 2015; Rosa, 2005). However, the similarity of these forms with discoidal inorganic minerals (e.g.,

Seilacher, 2001) makes a biotic origin unlikely. For example, the displacement of sediment near the border of one of the specimens (Fig. 14C) is comparable to the structures that arise from the displacive growth of crystals (Seilacher, 2001). Additionally, the lobed arrangement of the radial grooves in our samples is also similar to the morphology of pyrite (or marcasite) discs (see Fig. 11a, b of Seilacher, 2001), also known as pyrite rosettes (Cloud, 1973), although other minerals can generate similar morphologies. Therefore, these IB discs are considered pseudofossils.

The yellow flat discs are even more likely to represent pseudomorphs after pyrite dissolution (Fig. 14D–I). These discs are similar to those preserved as molds in terms of their size and presence of radially oriented ridges and lobed edges. However, the yellow discs differ from the other forms by their flat nature and iron oxide composition (Fig. 15J–N). The nanometric star-shaped and acicular crystals found in SEM investigations (Fig. 15) corroborate this interpretation since these crystal habits are found in goethite and hematite (Cornell and Schwertmann, 2003). For instance, star-shaped crystals of goethite after marcasite and needles of the latter mineral have been reported filling the chambers of microfossils originally filled with organics (Soliman, 2001). The presence of submillimetric cubes associated with some specimens may also attest to a pyritic origin, as previously noted for other pseudofossils (Cloud, 1973). Hence, in the case of the stellate discs, the originally precipitated marcasite may have been pseudomorphosed into iron oxyhydroxides later in diagenesis. The same mechanism may account for the *Choia*-like molds, but in this case, the original mineral left no discernible geochemical traces.

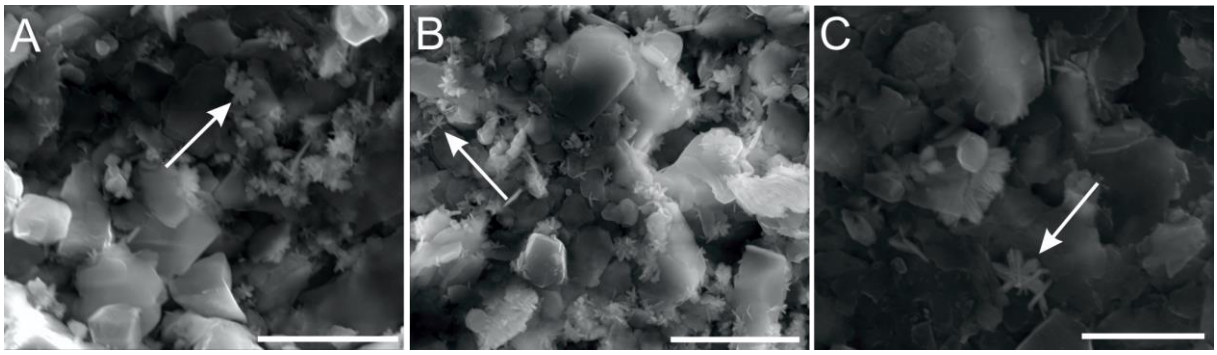



**Fig. 15**. A–B. Nanometric star-shaped and acicular crystals (white arrows) found in great abundance in the yellow discs from the IB (CAP/1A–584). C. Rare star-shaped crystals (white arrow) are also found in the rock matrix. Scales: 5 µm (A, B); 1 µm (C).

The IB discs might have resulted from the activities of sulfate-reducing bacteria using some source of $C_{org}$ and subsequently yielded the conditions for pyrite and/or marcasite precipitation (Southam et al., 2001). However, we acknowledge that at best, this interpretation is speculative since the validation of a microbial origin would require the study of isotopic fractionation in undissolved fresh discs.

Interestingly, the size, shape, and preservation of the yellow discs are quite similar to problematic circular remains reported from intertillite beds of the Neoproterozoic Maikhanuul Formation (Serezhnikova et al., 2014), albeit the latter have been interpreted as being related to microbial colonies. This hypothesis is based mainly on the fact that the disc diameters are normally distributed and the discs are enriched in titanium and iron and bear nanometric particles that the authors described as “bacteriomorph structures” (Serezhnikova et al., 2014). However, it seems that some of the “bacteriomorph structures” represent the same crystal habit observed in the star-shaped nanocrystals reported here. Considering their Fe composition and similarity to the crystal habits of iron oxides, the Maikhanuul star-shaped submicrometric forms are also more parsimoniously interpreted as small crystals of goethite and/or hematite.

## 8. Discussion

### *8.1. The Ediacaran soft-bodied fossil record in South America*

Deposits of Avalonian age bearing Ediacaran macrofossils are usually rare. Specifically, in South America, the Itajaí Group represents one of the earliest records of such a biota. Other Ediacaran fossil assemblages are generally more recent. For example, *Nemiana* was reported from the siliciclastic deposits of the Puncoviscana Formation in Argentina (Aceñolaza and Aceñolaza, 2007; Aceñolaza et al., 2009), but detailed studies employing polished sections to test other possible origins for these simple discs are lacking. In addition, Escayola et al. (2011) proposed an early Cambrian age for this unit, coeval with 540–535 Ma volcanic activity.

Discoidal structures assigned to *Aspidella* have also been reported from the Cerro Negro Formation in Argentina (Arrouy et al., 2016), but these structures occur above deposits containing *Cloudina* fossils (Gaucher et al., 2005); hence, they are

likely to be late Ediacaran to early Cambrian in age. Their interpretation as body fossils also requires further investigation (Inglez et al., 2019).

In Brazil, putative Ediacaran soft-bodied organisms have been described in siliciclastic rocks in the Jaibaras Basin (Barroso et al., 2014). However, later reinterpretations of the geology and fossil content showed that the studied sections are part of the Silurian Ipu Formation (Parnaíba Basin, NE Brazil) (Barroso, 2016; Inglez et al., 2019). Consequently, these fossils are no longer considered to represent Ediacaran taxa (Barroso, 2016).

Finally, possible body fossils (*Aspidella*, *Intrites*, and *Sekwia*) have been described in the Camaquã Basin (southern Brazil), mostly in the ~559–540 Ma Santa Barbara Allogroup (Netto, 2012), with a maximum depositional age of 566 ± 6.9 Ma (Bicca et al., 2013). However, a microbial mat-influenced origin, such as that described by Menon et al. (2016), cannot be ruled out.

Therefore, the fossil assemblage reported here can be considered the oldest known Ediacaran biota in Gondwana and is associated with indisputable Ediacaran taxa. Although simple discoidal impressions in Ediacaran deposits do not always represent the holdfasts of large macroorganisms, the presence of *Palaeopascichnus* strongly corroborates the Ediacaran age of the deposits, broadening even further the paleobiogeographic occurrence of this important taxon.

### *8.2. The Itajaí Basin in the context of Ediacaran ecosystems*

With the exception of a few claims of a shallow paleoenvironment for the Avalon biota (Retallack, 2016), several works have noted that these biological communities developed in deep-marine settings, well below the photic zone (Mason et al., 2013). This conclusion agrees with the scarcity of well-developed MISS in these deposits (Droser et al., 2017). The association of Ediacaran organisms with abundant MISS is well known in the younger White Sea and Nama Assemblages (Gehling and Droser, 2009; Droser et al., 2017), and they may even be involved in the moldic preservation of Ediacaran organisms, according to the death mask model (Gehling, 1999; Liu, 2016).

In contrast to the Avalonian record (Droser et al., 2017), the Itajaí biota occurs within strata that represent shallower conditions (delta front and upper slope deposits) and are also associated with abundant microbially influenced surfaces (Figs. 8–11). In particular, fossils of *Palaeopascichnus* and *Aspidella* found in thin-bedded rhythmites ascribed to an upper slope setting (outcrop A16) occur in association with abundant reticulated tufted mats (Figs. 8, 9). Moreover, it is important to note that both body fossils and microbial surfaces are absent in the deep basin plain deposits in the IB studied thus far. In this sense, the IB may help to understand the early colonization of shallower (distal delta front and upper slope) – possibly photic (abundant microbial tufted mats and MISS) – settings.

Some long-lasting taxa of Ediacaran macroscopic organisms, such as *Palaeopascichnus*, occur in Avalonian and White Sea deposits. This taxon not only had a widespread geographical distribution but possibly also adapted to very different environments: deep-marine and aphotic settings vs shallower and photic settings. Thus, understanding the ecological changes and/or bias in the geological record of the Ediacaran is fundamental to the development of a better picture of the early evolution of macroscopic life and its relation to environmental conditions. The IB offers a unique perspective regarding its age and depositional environments, with a macroscopic biota that, although depauperate, can record the early adaptations to shallower settings by probably generalist organisms such as *Palaeopascichnus*.

## 9. Conclusions

The IB can help to answer important open questions regarding the early evolution of macroscopic benthic communities during the Ediacaran Period. The IB fossil record provides evidence of the first steps of the colonization of shallower environments, possibly within the photic zone. The body fossil assemblage occurs in upper slope and distal delta front deposits associated with abundant and exquisitely preserved microbial mats, including the well-known Arumberia morphology. This situation differs from that observed in the deep-marine Avalonian deposits of Canada and England, where MISS are rarer. The discoidal impressions identified within the *Aspidella* plexus suggest the presence of frond-like macroorganisms. The remarkable presence of the indisputable Ediacaran taxon *Palaeopascichnus* further correlates the

IB with the other Ediacaran deposits and, together with the radiometric dating (ca. 563 Ma), marks this unit as the oldest known occurrence of Ediacaran body fossils in Gondwana.

**Acknowledgments**

The authors are grateful for the support of the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP - Grant 2016/01827-4 and Grant 2018/21886-0), the Programa de Pós-Graduação em Ecologia e Recursos Naturais (PPGERN – UFSCar), and the Programa de Pós-Graduação em Geologia (PPGeo – UNISINOS). This work was also supported by La Région Nouvelle Aquitaine. We acknowledge C. Fontaine, C. Laforest for laboratory support at the University of Poitiers. The authors would like to thank the Brazilian Synchrotron Light Laboratory (LNLS-CNPEM) and the Brazilian Nanotechnology National Laboratory (LNNAno-CNEPM) for their technical support and for providing infrastructure for the SR-μXRF (proposal 20170438; 20171031), SEM/EDS (proposal 21836 and 23684) and μ-CT (proposal 20415) analyses. We also thank Petrobras Research Centre (CENPES) for all of their support with the palynological preparation, as well as the technical help of Igor Augusto Nascimento de Almeida and Gilton Braz de Aquino Filho. The authors are also grateful to Laboratório de Ecologia (UFMS), Alan Eriksson and Alêny Lopes Francisco Batista for enabling the stereomicroscope investigation. We thank the Laboratório de Preparação de Lâminas Delgadas of UNISINOS and the Setor de Laminação of UNESP (Rio Claro) for thin section preparation. We thank Fabiano Emmanuel Montoro for assistance with the SEM/EDS, and Gabriel Baréa Barros and Bianca Becker Kerber for their support in field activity. Finally, we would like to gratefully acknowledge all of the help we received from the citizens of Apiúna city during field investigations.

**Supplementary information for "The oldest record of Ediacaran macrofossils in Gondwana (~563 Ma, Itajaí Basin, Brazil)"**

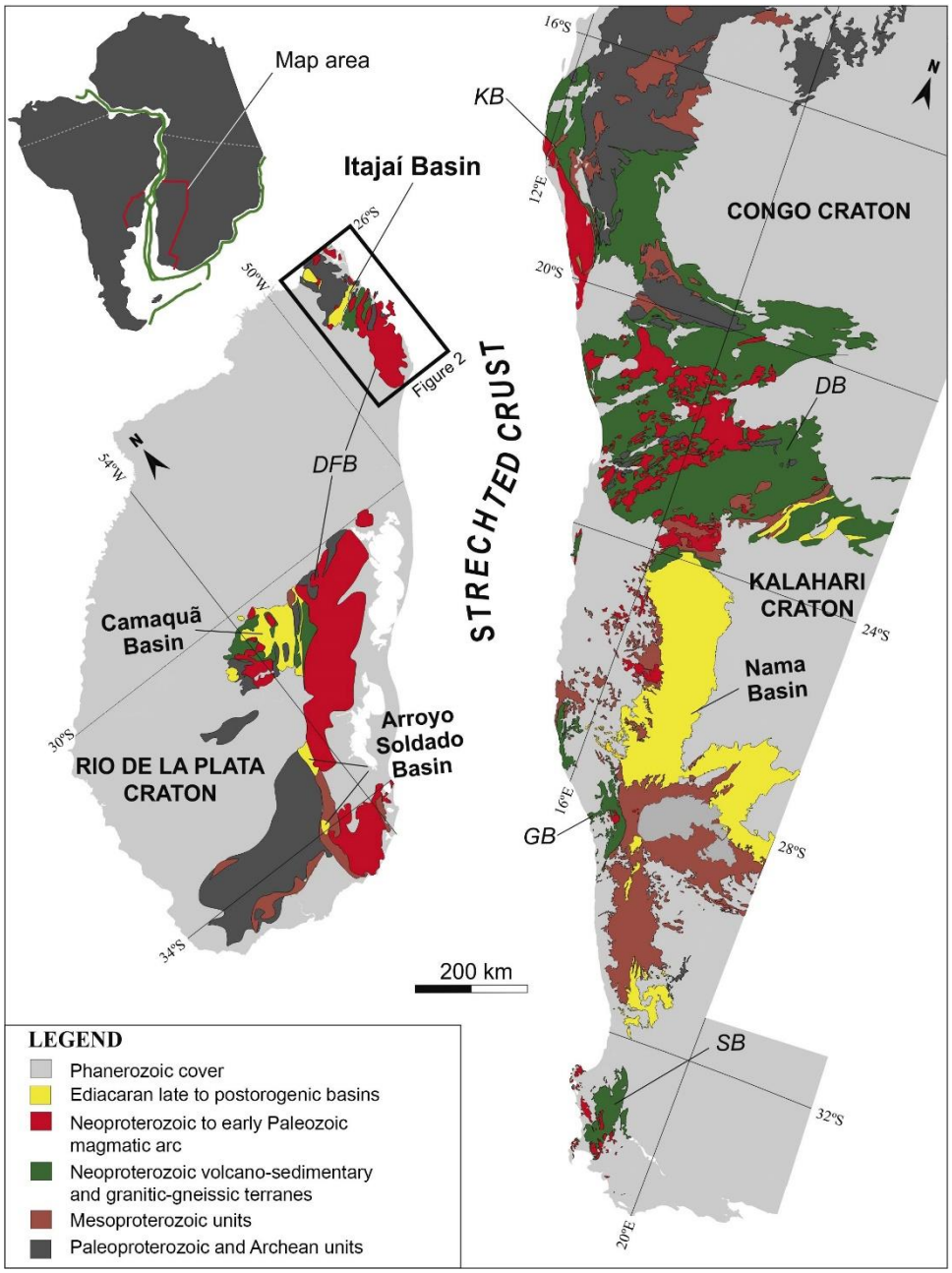



**Figure S1.** Paleogeographic reconstruction of Neoproterozoic belts. The basins with described Ediacaran biota are indicated (modified after Guadagnin et al. 2010). DFB – Don Feliciano Belt; KB – Kaoko Belt; DB – Damara Belt; GB – Gariep Belt; SB – Saldania Belt.

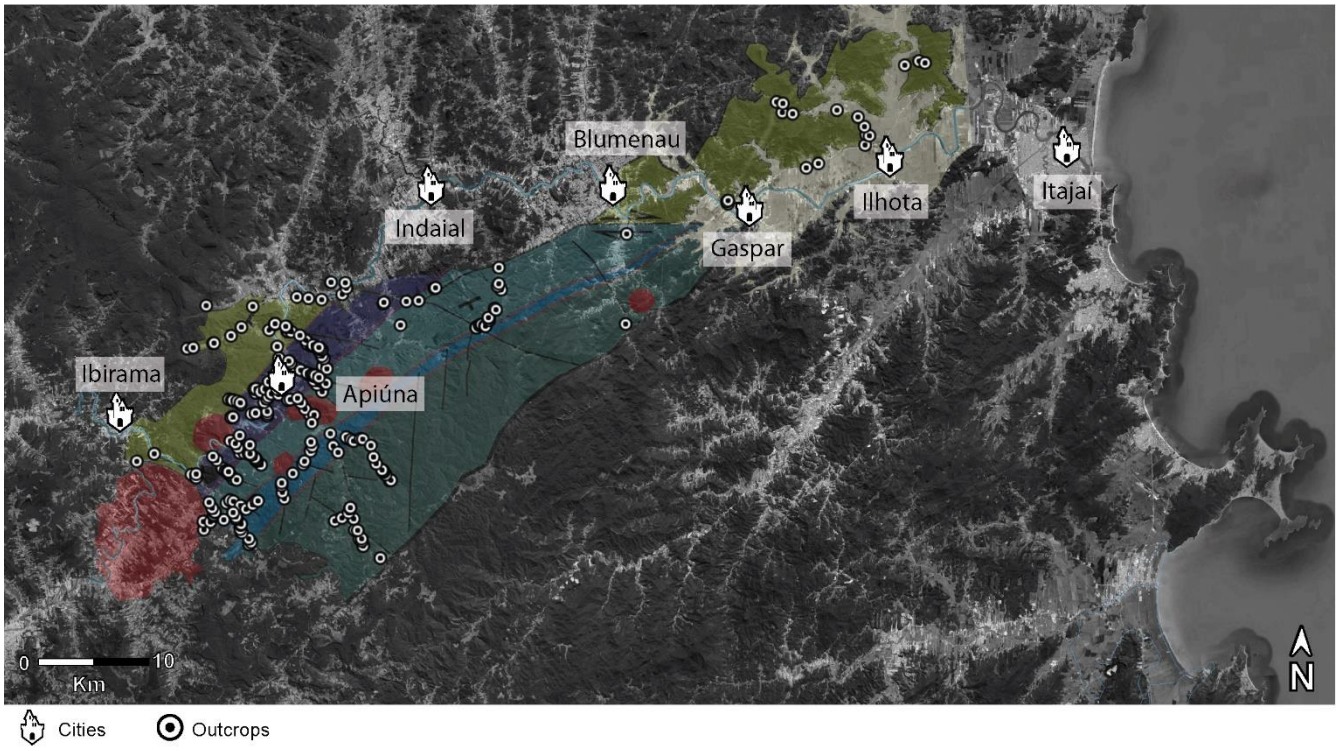



**Figure S2.** Geologic map and localization of all the outcrops prospected during field investigations.

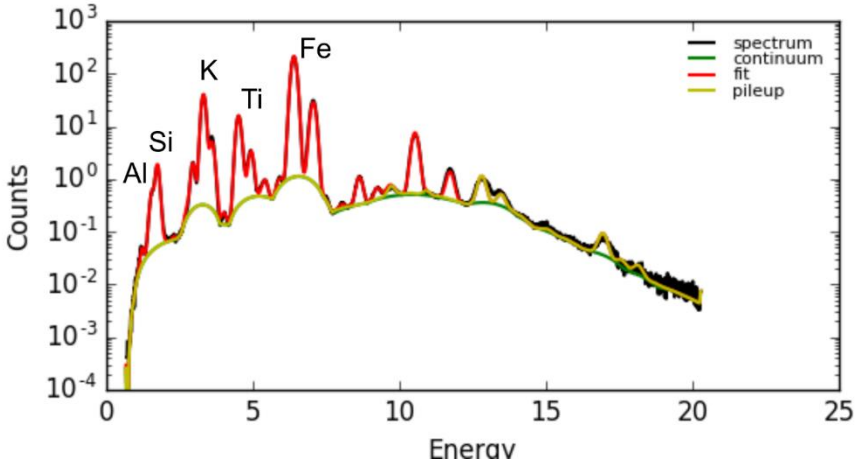



**Figure S3.** SR-μXRF point analysis of three-dimensional reticulate mats showing the presence of Al, Si, K, Fe and Ti.

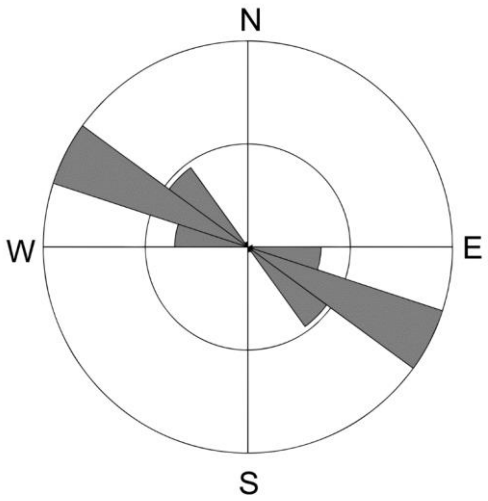



**Figure S4.** Measured orientations of Arumberia crests (n = 79) recovered in the outcrop AF236.

## Supplementary Text 1 – Palynological artifacts

Attempts to recover palynomorphs through acid maceration procedures did not yield discernible microfossils, but only putative organic spheres. Through the acid maceration of 128 samples from 15 outcrops using the method of Grey (2005) and a modified version that included filters at every step to maximize recovery, we were able to find organic remains in only one level of an outcrop in DS2 (Fig. 19). These carbonaceous structures present a spherical morphology with a granular appearance (“sponge-like”) and great variation in size (from 20 to 560 μm in diameter). Some more elongated and conjoined specimens were also observed. Bubbles were visible inside some of the specimens (Fig. 19A, D, G, I).

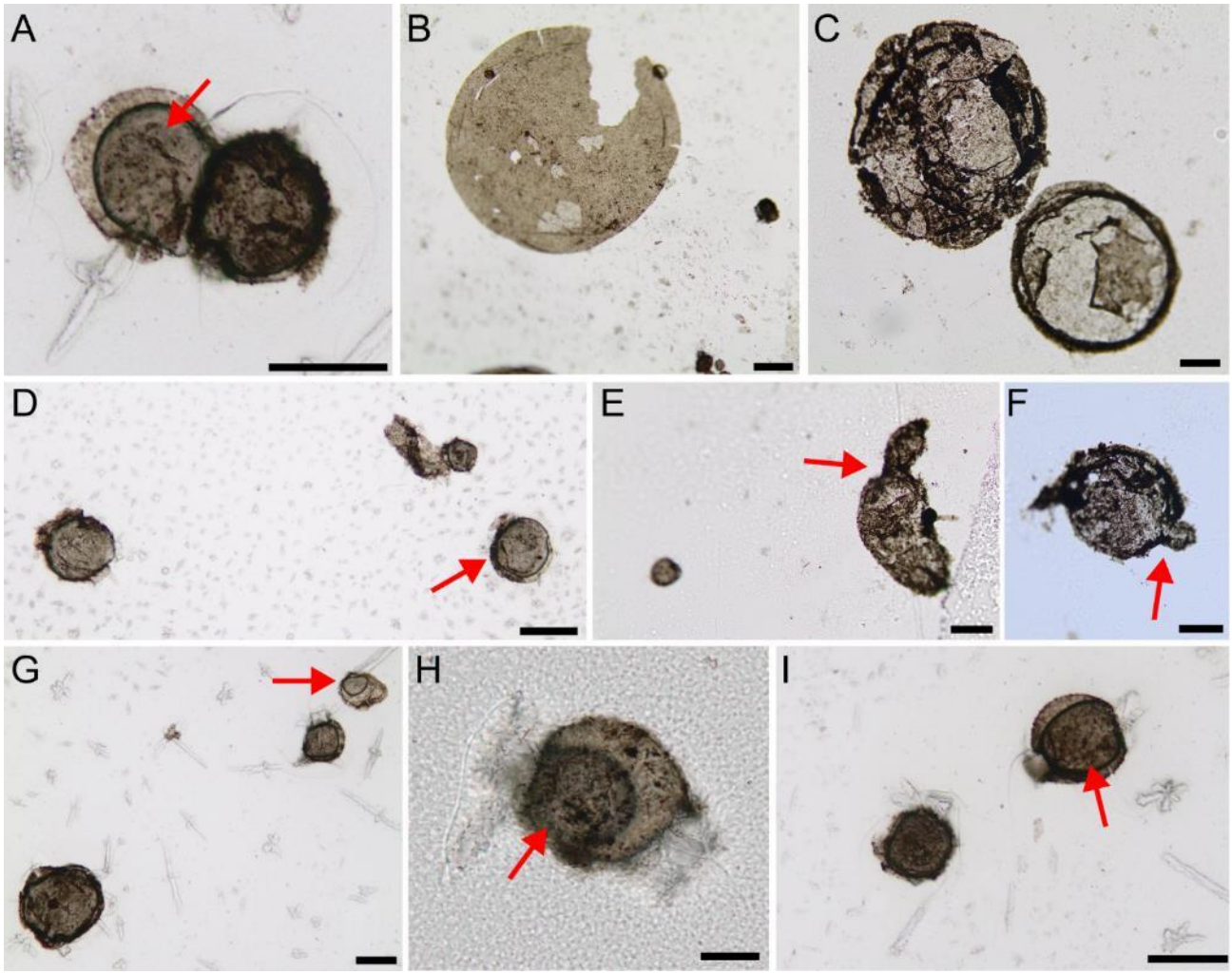



**Figure S5.** Palynological artifacts created after acid maceration of samples from the Itajaí Group that are rich in finely dispersed organic matter (CAP/1F–06, CAP/1F–07); note bubbles inside some of the organic spheres (red arrows). Scales: 50 µm (A, C–G, I), 100 µm (B), 10 µm (H).

These organic spheres present a remarkable resemblance to leiospherid acritarchs, but their granular texture, presence in the first steps of acid dissolution as supernatants, wide variations in size, conjoined forms and the occurrence of bubbles inside some of the vesicles (Fig. 19) suggest an origin by flocculation of finely disseminated organic matter, similar to those observed and interpreted by Grey (2005) as artifacts. Strikingly, the presence of bubbles inside the structures may suggest that they originated by aggregation of organic particles around gas bubbles of silicon tetrafluoride ($SiF_4$), released during the HF reaction with silicates. In fact, Fuxing and Qiling (1982) gave similar interpretations when studying the behavior of finely

disseminated organic substances during acid maceration. These authors were able to show that this process can indeed create spherical pseudofossils that can be confused with true microfossils.

The apparent absence of true organic microfossils in the IB can reflect some diagenetic alteration and/or weathering of the rocks in the exposed outcrops studied here. Nevertheless, the observation that palynological artifacts can easily occur highlights the caution necessary when dealing with simple organic vesicles from Precambrian rocks, especially regarding the morphological group of the leiospherids.

## 4 ARTICLE TWO

# *Beggiatoa*-like *in situ* communities from the Ediacaran Itajaí Basin (~563 Ma) – the expansion of sulphide oxidizing bacteria in the Ediacaran Period

**Abstract**.

Precambrian filamentous microfossils are common and diverse. Nevertheless, their taxonomic assignment can be difficult due to their overall simple shapes typically lacking in diagnostic features. Here, we report *in situ* communities of well-preserved, large filamentous impressions from the Ediacaran Itajaí Basin (ca. 563 Ma) of Brazil. The filaments are uniserial (unbranched) and can reach up to 200 µm in width and up to 44000 µm in length. They occur as both densely packed or sparsely populated surfaces, and typically show a consistent orientation. Although simple in shape, their preferred orientation suggests they were tethered to the seafloor, and their overall flexibility (e.g. bent, folded, and twisted) supports a biological (rather than sedimentary) affinity. Biometric comparisons with modern filamentous groups further support their biological affinity, suggesting links with either large sulphide-oxidizing bacteria (SOB) or eukaryotes. Their association with other complex macrobiota (e.g. frondose organisms, *Palaeopascichnus*) suggest that they likely played an important role in the ecological dynamics of these early benthic communities by providing firm substrates for metazoans to inhabit. It is further hypothesized that the dynamic redox condition in the latest Ediacaran, with the non-continuous rise in oxygen concentration and periods of hypoxia, may have created ideal conditions for sulphide-oxidizing bacteria to thrive.

**Keywords**: Filamentous Fossils, Ediacaran Ecosystems, Avalon Assemblage, Itajaí Basin, *Beggiatoa,* Sulphide-Oxidizing Bacteria.

## 1. Introduction

Simple, relatively large (ca. >30 µm) unbranched filamentous (UF) microfossils are common in the Precambrian fossil record (Knoll, 1982; Knoll et al., 1991; Butterfield et al., 1994; Javaux and Knoll, 2017). Depending on their size and morphological complexity, these filaments are typically interpreted as either cyanobacteria or eukaryotes (Tynni and Donner, 1980; Nyberg and Schopf, 1984; Butterfield et al., 1994; Butterfield, 2015; Sergeev et al., 2016; Bengtson et al., 2017). These fossils are usually investigated by means of palynological maceration or thin sections of cherts and phosphatic rocks. However, in rare circumstances, filamentous organisms can be preserved as carbonaceous compressions (Cohen et al., 2009; Tang et al., 2015) or even as casts and moulds in siliciclastic rocks (Callow and Brasier, 2009b; Liu et al., 2016b; Liu and Dunn, 2020), the latter making them difficult to differentiate from trace fossils (Droser et al., 2005; Jensen et al., 2005, 2007; Sappenfield et al., 2011).

Nevertheless, even when a body fossil origin is corroborated, the possibility that some of these occurrences represent the remains of large filamentous sulphur-oxidizing bacteria (LFSOB), similar to the modern *Beggiatoa* and *Thioploca*, is poorly explored. Modern LFSOB are ubiquitous in marine and freshwater environments where $H_2S$ and oxygen geochemical gradients are prevalent (e.g. environments at the interface of euxinic and oxic conditions; (Jørgensen et al., 2015; Strohl, 2015b). Yet, only few studies have suggested the presence of SOBs in the fossil record (Peckmann et al., 2004; Bailey et al., 2013; Pierre et al., 2015). This is due, in part, to their simple morphology and overall morphological similarities with cyanobacteria (Larkin and Strohl, 1983; Strohl, 2015a).

Here, we report exceptionally preserved *in situ* communities of large unbranched filamentous microorganisms from the Ediacaran of the Itajaí Basin (IB) of Brazil (~563 Ma, Becker-Kerber et al., 2020). Based on morphological and ecological comparisons with modern analogues, these fossils are interpreted as the remains of large filamentous sulphur-oxidizing bacteria (LFSOB). Their presence in Ediacaran (Avalonian-Assemblage; Boag et al., 2016) deposits from Brazil (this report), Newfoundland (Liu and Dunn, 2020) and England (Callow and Brasier, 2009b) suggest that they were important components of these earliest complex macroscopic ecosystems.

## 2. Morphology and ecology

Over 1,600 individual specimens (Fig. 1) were investigated as part of this study (see methods). Filament size range from 33 µm to 193 µm wide (mean = 68.9 ± 0.43 µm, n = 1636), and from 1270 µm to 44000 µm long (mean = 11000 ± 717.8 µm, n = 117). All filaments have remarkably consistent widths from one extremity to another, varying only ~13 µm (on average). In many cases, their extremities occur as blunt (or slightly tapered) terminations. Filament surfaces are typically smooth, lacking any discernible ornamentation (although see Fig. 1c, 2b) (Becker-Kerber et al. submitted). Despite the high number of individuals investigated, we found no evidence for differentiated cell-types such as attachment and/or rhizoid-like structure, or possible reproductive bodies. Filaments can be either sparsely or densely concentrated on bedding planes (Fig. 1, 2, Supplementary Figure 1–3). Some of the densest surfaces showcase up to 50 individuals/cm$^2$.

Although simple in form, the filaments can be differentiated from abiogenic structures. For example, the absence of vertical continuity or vertical disruption of sediments below or above the filaments (as seen in polished sections) is particularly helpful in refuting some abiogenic structures such as fractures, syneresis cracks, and petee structures. Furthermore, the non-linear nature of many specimens, including examples that are curved, bent, overlapping, and even looping (Fig. 1) also supports a biological affinity. Additionally, their preservation in positive epirelief (on the tops of beds) rules out an abiotic origin by tool marks. Moreover, the overlapping nature of some specimens (e.g. Fig. 1c–d), including examples that are highly interwoven (Fig. 2a–b), combined with the absence of cross-cutting relationships and preferential orientation of the filaments (Fig. 2e), all supports a body fossil, rather than a trace fossil or a tectograph (see ref. Becker-Kerber et al., 2020) interpretation.

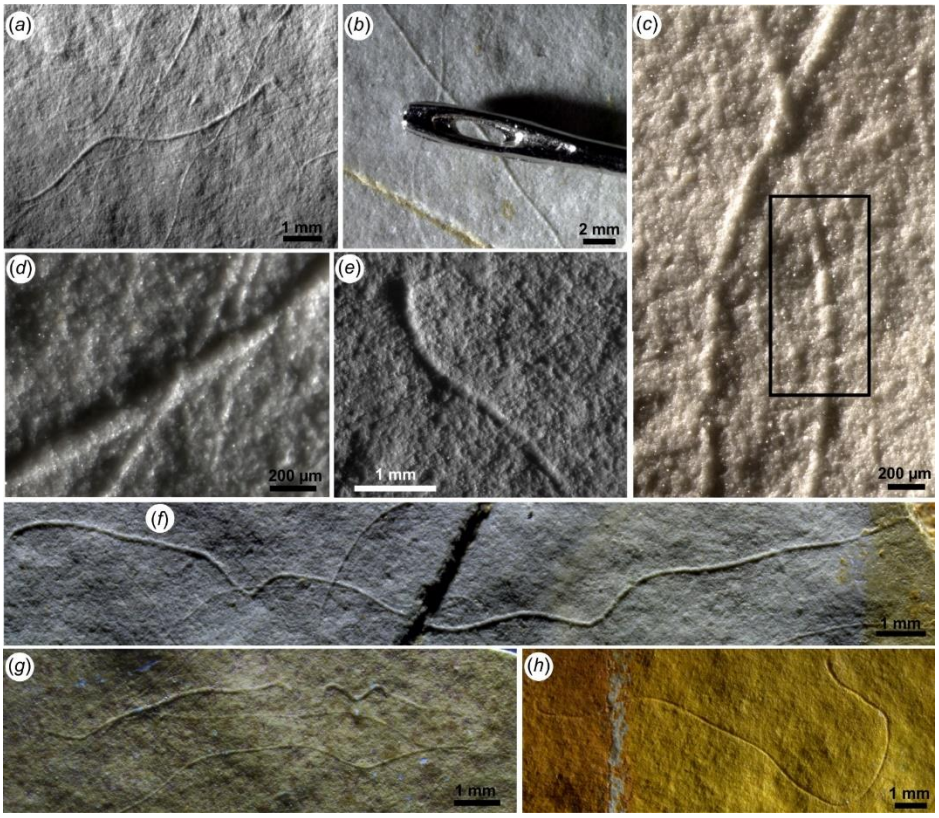



**Figure 1. Filamentous fossils from the Itajaí Basin (a-h)**. Note possible cell-like arrangement in (c), overlapping (not cross-cutting) relationships in (d), blunt terminations in (e), and the long and sinuous nature of the filaments (f-h).

The filaments are interpreted as being originally composed of soft tissues, given that they were capable of bending, folding, and twisting plastically without breaking (Fig. 2a, b). Several specimens display sinuosity (Fig. 1, 2) and even a high degree of interlacing with other filaments (Fig. 2a–b). Interestingly, the latter is more common on less populated surfaces, indicating that this arrangement is not a consequence of dense assemblages.

Formerly buried extremities (Fig. 2c) and specimen alignment (Fig. 2e, Supplementary Fig. 1–3) suggest *in situ* preservation and a benthic habit. The oriented populations also suggest the influence of gentle bottom-water currents that did not disarticulate or detach the specimens from the substrate prior to fossilization. Given the absence of evidence for strong sediment reworking and/or storm deposits, the filament orientation agrees with the interpretation (Becker-Kerber et al., 2020) of an upper slope setting dominated by millimetre-scale intercalations of siltstones and claystones. In rare cases, filament overlapping patterns can even allow for inference of the likely sequence of filament superposition prior to burial (Fig. 2f, Supplementary

Fig. 4). This further corroborates the *in situ* nature of these populations, as well as suggesting a potential vertical mode of life, with basal portions of the filament likely buried or attached to the substrate.

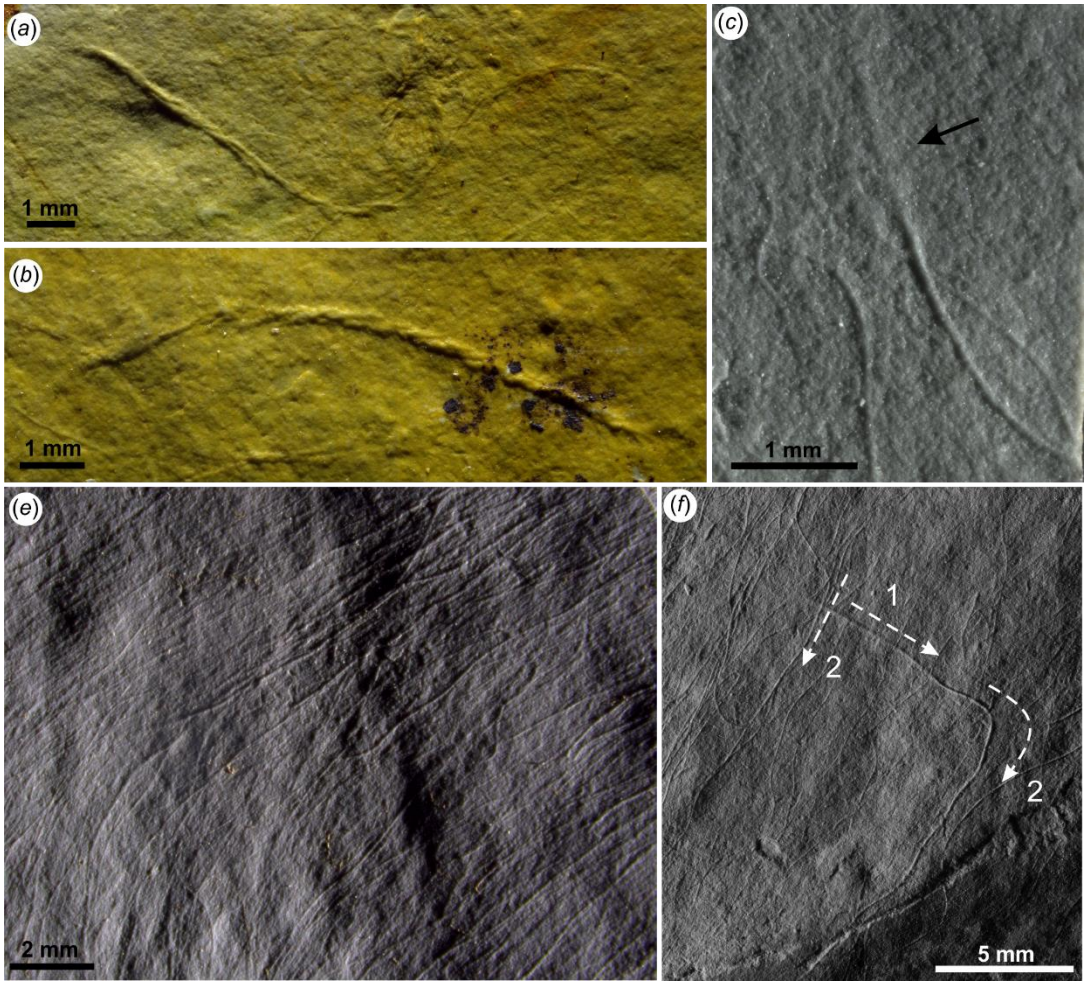



**Figure 2**. **Disposition of the filaments on the bedding plane**. Highly interwoven individuals (a-b), partially buried extremities (c), densely populated surfaces with preferential orientation (e), and sequentially orientated specimens (f).

Interestingly, it may be possible to interpret the original life position of the microbial filaments based on their surficial expression. As seen in figure 3, a single bedding plane showcases two distinct regions: a region with a high density of filaments next to a slightly raised section that has a pustular (“old elephant skin” of Runnegar and Fedonkin (1992) texture and lacks filaments altogether. In planar view, these two regions are divided by a straight to sinuous positive-relief ridge (Fig. 3). Since the bedding plane is smooth and continuous between both regions, it is unlikely that this feature represents a fracture (or a different bedding plane altogether), and we therefore interpret this as an original surface. Filaments that extend from the high-density region

apparently disappear into the low-density surface once they reach the ridge (Fig. 3c–d), rarely leaving more than a faint impression. In this sense, we interpret the pustular low-density region as the remains of a microbial mat cover (Microbially-Induced Sedimentary Structures [MISS] of Noffke (2001) that overlay the filament-rich layer. The exposure of the filamentous under-mat surface likely resulted from the overlying microbial mat being torn-off by a rare high-energy bottom-current. Sedimentary structures interpreted as “rolled-up” microbial mats (Supplementary Fig. 5) are common in the region, and suggest that a significant portion of the filaments resided within the substrate and/or microbial mats prior to burial.

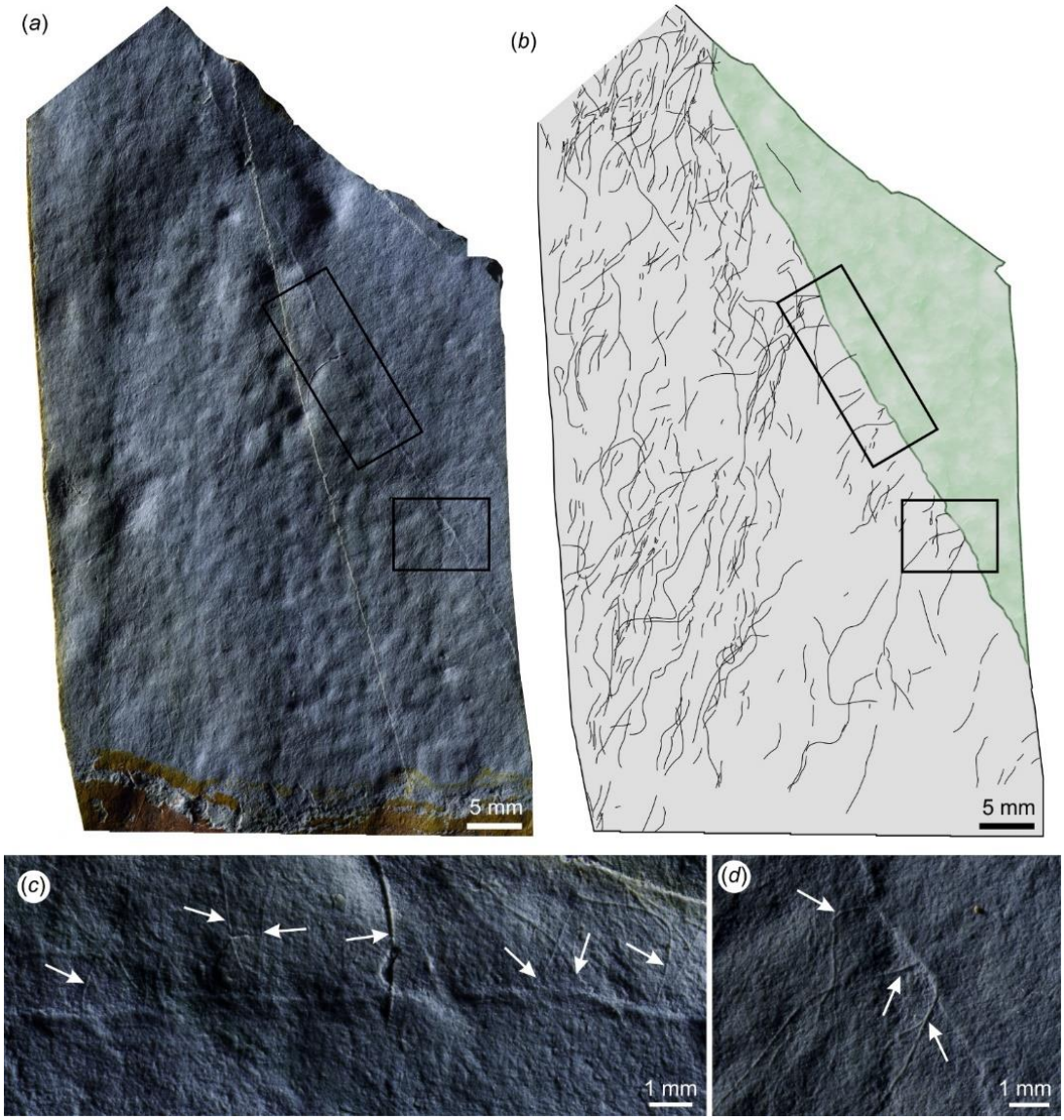



**Figure 3. Sample showing original bedding plane with an exposed, filament-rich lower surface**. (a-b) Bedding plane photograph (a) and interpretive drawing (b) showing the filaments and the positive-relief ridge between the lower and upper

surfaces. (c-d) Close-up of (a) displaying the filaments disappearing at the positive ridge.

To better constrain the comparisons with modern filamentous groups, we created a database with size ranges of unbranched filamentous organisms (cyanobacteria, LFSOB, and eukaryotes) (See references in Supplementary Table 1). The results suggest that the Itajaí Basin filaments exhibit values closer to those observed for sulphur-oxidizing bacteria (e.g. *Beggiatoa*) and eukaryotes rather than cyanobacteria (Fig. 4). This is also the case for the calculated biovolume ($\pi/4 \times W^2 \times L$) of these groups (Fig. 4).

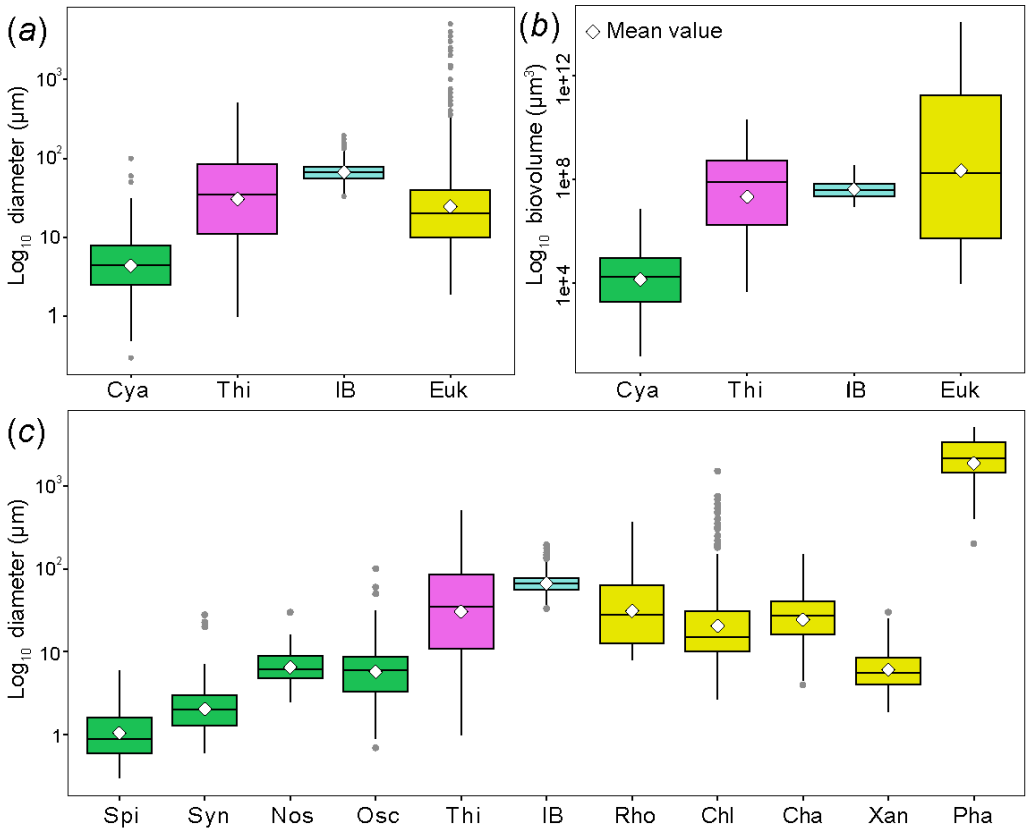



**Figure 4. Biometric comparison of the IB filaments and modern groups of unbranched filamentous organisms**. Box plots for the diameters (a) and estimated biovolumes (b) of major groups and IB filaments, and box plot of the diameters of the same groups divided in their main taxa (c). Green boxes = Cyanobacteria, purple = Thiotrichales, light blue boxes = Itajaí Basin (IB) filaments, yellow: eukaryotes. Cya = Cyanobacteria; Thi = Thiotrichales; IB = Itajaí Basin filaments; Euk = Eukarya; Spi = Spirulinales; Syn = Synechococcales; Nos = Nostocales; Osc = Oscillatoriales; Rho =

Rhodophyta; Chlorophyta; Cha = “Charophyta”; Pha = Phaeophyceae. Data from Supplementary Table 1.

**3. Biological affinities**

Interpreting the biological affinities of morphologically simple filaments by shape alone is difficult and is only confounded when applied to fossil data. Yet, large datasets based on *in situ* communities, when combined with ecological characterization derived from sedimentary facies analyses, can allow for hypotheses concerning the likely biological relationships of these forms, or even help elucidate the likely mode of life of such organisms.

The large filaments herein described from the Itajaí Basin of Brazil exhibit comparable size ranges to both LFSOB and eukaryotes, but they differ from most of the reported size-ranges of modern cyanobacteria (Fig. 4). Indeed, the diameter of filamentous cyanobacteria is typically < 100 µm (Fig. 4), while the largest IB filaments reported here can reach widths of nearly 200 µm (Supplementary Fig. 6). On the other hand, modern filamentous sulphide-oxidizing bacteria can attain exceptionally large dimensions: populations of the filamentous genus *Beggiatoa* were found with individuals measuring up to 200 µm in diameter (Larkin and Henk, 1996). In fact, the largest bacteria known is *Thiomargarita*, a SOB that can reach up to 750 µm in diameter (Schulz, 2006). The lengths observed for the IB filaments, as well as the calculated biovolumes, are also akin to the values observed in large LFSOB and eukaryotes (Fig. 4).

Given the simplicity of the filamentous fossils reported here, especially considering the lack of any diagnostic characters such as specialized anchoring structures, it is difficult to make a more robust palaeobiological interpretation of their affinities. However, the consistent width of the IB filaments suggests a closer affinity with modern large LFSOB than with unbranched filamentous eukaryotes. For instance, modern unbranched filamentous eukaryotes are rarely uniform along their entire length, and typically exhibit a complex set of specialized cellular characters. For example, *Bangia* shows clear variations in filament width towards the apex (uniseriate to multiseriate thalli), rhizoid attachments, and specialized reproductive structures (Sutherland et al., 2011). Chlorophytes with similar sizes to the IB filaments (e.g., *Chaetomorpha*, *Urospora*) typically show a pronounced morphological complexity, including differentiated holdfasts, constricted septa (i.e., *Chaetomorpha*), and

distinctive distal tapering (Lokhorst and Trask, 1981; Blair, 1983; Vahedi and Pasbakhsh, 2015). Given the number of filaments (>1600) investigated from IB deposits and their exceptional preservation, it is most parsimonious that additional morphological characters are in fact absent (rather than not preserved) from the external morphology of the filaments.

Finally, the *in situ* preservation of the filaments from the Itajaí Basin allows a unique opportunity to understand aspects of their palaeoecology and perhaps even their preferred metabolic pathway. Their benthic vertical mode of life (Fig. 5), partially prostrate, and perhaps even partially buried, is remarkably similar to the ecology of modern LFSOB (Jørgensen et al., 2015; Strohl, 2015b). Indeed, large filamentous sulphide-oxidizing bacteria can colonize extensive seafloor areas in dysoxic settings, building large communities that live attached and/or partially buried in the substrate (Schulz et al., 1996). Some species, like *Beggiatoa* and *Thioploca*, can even show motility through gliding and the capacity to adjust their positions accordingly to local geochemical variations (Teske and Nelson, 2006). The presence of sequential orientations (Fig. 2f, Supplementary Fig. 4) in the IB filaments shows that these organisms were able to return to a partial vertical position following an event that felled them. This suggests some degree of control in their position at the sediment-water interface, possibly reflecting some type of gliding motility.

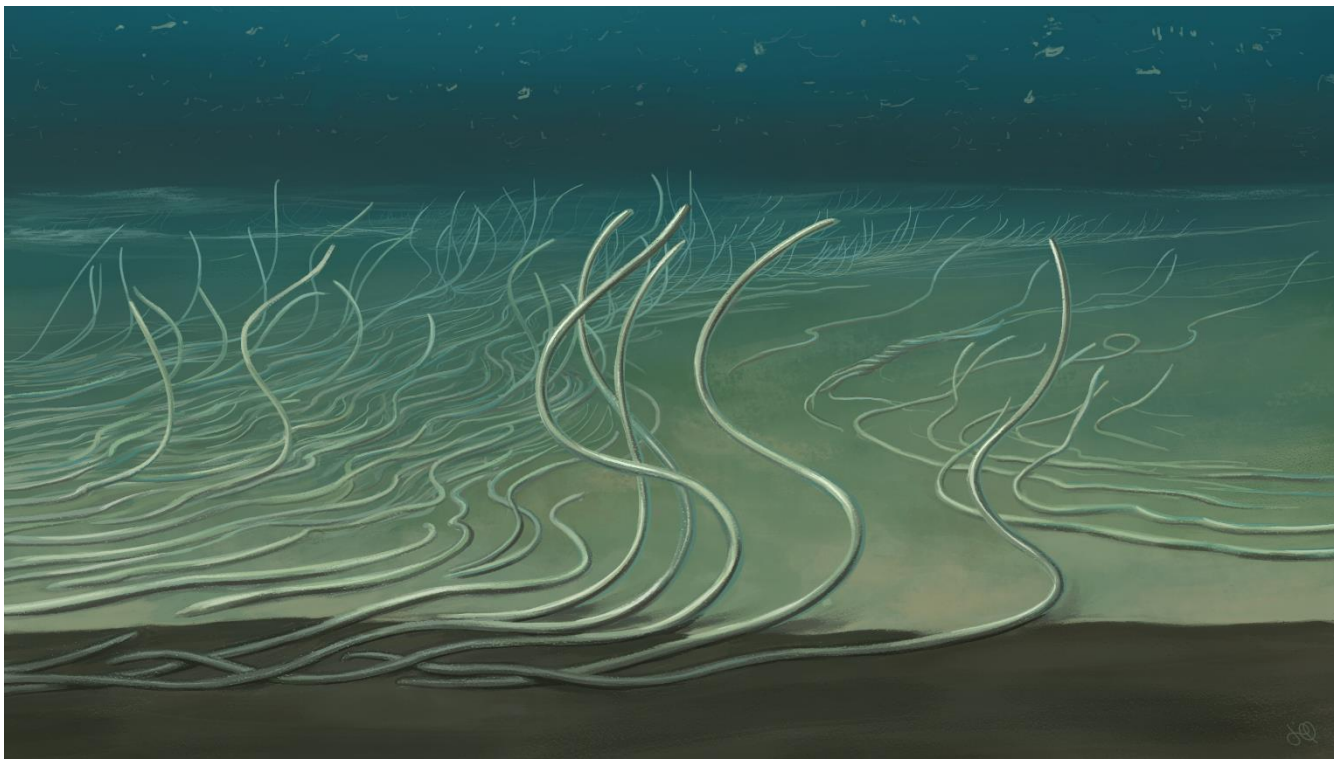


**Figure 5**. Artistic reconstruction of the possible life habits of the Itajaí Basin filaments.

In addition to the Itajaí Group, large filaments have been reported from the Longmyndian Supergroup (~567-556 Ma) of England (Callow and Brasier, 2009b, 2009a), and in the Trepassey Formation (~565-560 Ma) of Newfoundland, Canada (Liu et al., 2016b). Other possible sulphur-oxidizing bacteria were observed in phosphorites of the Doushantuo Formation (Bailey et al., 2013).

Recently Liu and Dunn (2020) reinterpreted the large filaments of Newfoundland as stolon-like structures connecting frondose organisms. However, among the thousands of filaments investigated on 38 surfaces by the authors, only a handful of cases of thicker (≥ 1 mm) and much longer (up to 4 meters) filaments were observed to cross-cut (or terminate at) frondose organisms. The “typical” filament size reported varied between 100 to 1000 µm wide and 2 to 40 cm long, values that are not far from the dimensions of LFSOB (see Supplementary Table 1; e.g. *Thioploca*, Jørgensen and Gallardo, 1999). Thus, we propose that these filamentous impressions of Newfoundland (and elsewhere) may represent remains of LFSOB, however the stolonic interpretation may remain valid specifically for the larger filaments found adjacent to the fronds (especially given the large range in sizes reported (Liu and Dunn, 2020).

## 4. Sulphide oxidizers, Ediacaran macrobiota and dynamic oxygen levels in the Ediacaran

The chemoautotrophic metabolism of LFSOB relies on sulphides (e.g., $H_2S$) as electron donors and oxygen or nitrate as electron acceptors (Teske and Nelson, 2006). Therefore, they are adapted to live in settings with significant geochemical gradients (Nelson et al., 1986; Teske and Nelson, 2006), more specifically, at the interface between sulphidic and low oxygenated zones. During the late Neoproterozoic, the non-continuous and episodic oxygenation of the oceans (Bowyer et al., 2017) could have created favourable micro-oxic conditions ideal for SOB metabolism. Indeed, recent works (Sperling et al., 2015; Tostevin et al., 2016; Bowyer et al., 2017) propose that Ediacaran oceans were marked by dynamic redox conditions, with persistent and frequent low-oxygen levels. Consequently, this scenario would be highly favourable for a widespread development of SOB in a range of different settings.

If correctly interpreted, the widespread distribution (both temporally and geographically) of filamentous SOB would have played an important role in mitigating the biogeochemical cycles of the late Neoproterozoic. For example, because these organisms also use and accumulate nitrate (as an alternative electron acceptor) (Fossing et al., 1995; Zopfi et al., 2001), their metabolism could have impacted the nitrogen cycle (and fixation) in the Ediacaran oceans, increasing primary productivity and/or leading to eutrophication (Sayama, 2001; Teske and Nelson, 2006). Likewise, their metabolic activities may have contributed to the S and C cycles of marine ecosystems (Jørgensen, 1977; Fossing et al., 1995), and would have contributed to the growing sulphate concentrations of Ediacaran oceans (Kunzmann et al., 2017). In fact, recent studies have shown that biologically-driven sulphide oxidation rates can be three (or more) orders of magnitude higher than abiotic rates (Luther et al., 2011).

If we are correct, the increasing oxygen levels of the late Neoproterozoic and early Phanerozoic would have acted as a double-edged sword for SOB. First off, the rise of oxygen would have created widespread hypoxic conditions that favoured the development of chemosynthetic microorganisms and associated macrobiota. However, further oxygenation would have restricted sulphur-based communities and may have affected biotic events throughout the middle-late Ediacaran (Darroch et al., 2015b; Muscente et al., 2018, 2019), such as the changes in the taxonomic composition and ecology of the Avalon and White Sea assemblages. Meanwhile, new adaptations to increasingly oxygenated environments may have promoted the colonization of shallower settings by the typical biota of the White Sea. The diversification of more metabolically active (and more complex) macro-organisms prior to the Ediacaran/Cambrian transition may have played a role in shaping the evolutionary novelties of the Cambrian radiation event (Darroch et al., 2015b; Muscente et al., 2019).

It is also interesting to speculate on the ecological and evolutionary impacts of this SOB expansion during the early evolution of complex macroscopic life. If correct, their ubiquitous presence in deep-water, Avalonian-age deposits (Callow and Brasier, 2009b, 2009a; Liu et al., 2016b) suggests that they were relatively common in the early benthic communities at this time as chemosynthetic bacteria are an important primary producer in modern deep-water ecosystems (Felbeck and Somero, 1982). Moreover, as high levels of sulphide are typically toxic to aquatic invertebrates (Grieshaber and Völkel, 1998), the dominance of LFSOB could have served not only as a food source,

but also as a detoxification mechanism exploited by macroscopic organisms. Symbiotic relationships between Ediacaran organisms and chemosynthetic bacteria have been proposed (McMenamin, 1998; Dufour and McIlroy, 2017), and should continue to be investigated as an alternative to Osmotrophy (Laflamme et al., 2009). Finally, based on comparisons with the strict ecology of recent sulphur-oxidizing bacteria, another implication of the widespread presence of SOB in Avalonian deposits is that the Ediacaran organisms possibly evolved in oligotrophic environments, near the interface between hypoxic and sulfidic conditions, where these bacteria can maintain their metabolism.

## 5. Conclusions

Here we present a new association of large filaments from the Ediacaran of the Itajaí Basin. These well-preserved structures bear morphological and ecological similarities with large sulphide-oxidizing bacteria such as *Beggiatoa*. The apparent widespread occurrence of such organisms during the middle-late Ediacaran suggests that they likely contributed to the biogeochemical patterns of the N and S cycles. Moreover, the association of SOB with Ediacara biota suggests that they may have been important components of these early ecosystems, possibly playing important roles in the food chain, or in close ecological interactions with the Ediacaran biota.

## Methods

**Sampling**. Samples were recovered from upper slope, fine-grained rhythmites of the Depositional Sequence 2 of the Itajaí Basin (see Becker-Kerber et al., submitted, and references therein). These rhythmites comprise a millimetric intercalation of claystone and fine- to coarse-grained siltstone. These fossiliferous surfaces are associated with volcaniclastic and pyroclastic sediments, which likely played a major role in the high-fidelity fossilization observed in these beds (Becker-Kerber et al., submitted).

**Stereomicroscope and biometry**. We used the high magnification SteREO Discovery.V20 stereomicroscope coupled with an Axiocam camera at the Laboratório de Ecologia in the Universidade Federal de Mato Grosso do Sul. To ensure better characterizations of the microbial-rich surfaces and to avoid measuring the same specimen more than once, we imaged the entire surface by using consecutive snapshots that were later joined through image processing. We then selected

appropriate specimens and used the ZEN software to make all width measurements (n = 1636). When investigating original length, possible changes in the diameter, and biovolume calculations, we choose only complete (both extremities visible) specimens (n = 117; measuring each sample three times). For the biometric comparison, we compiled data from published articles (see Supplementary Table). We considered the reported size for the entire unbranched filamentous structure (including sheath if applicable). We considered both lower and upper size limits of each taxon for diameter comparison. We used the formula $\pi/4 \times W^2 \times L$ for the biovolume calculation (Hillebrand et al., 1999). This allows for an estimation of the real value since: [1] we had to use only the upper size limit of the diameter and length because most of the works only reported the upper limit for the latter, and [2] taxa that are tapered can result in slightly overestimated values. The final database was processed with the R-studio software version 1.2.1335, with the ggplot2 package.

**Ethics**. This work has not involved any living subjects and conforms to the Ethics guidelines of the National Mining Agency (ANA, Brazil).

**Data accessibility.** Data available in this manuscript and its Supplementary Material

**Authors' contributions**

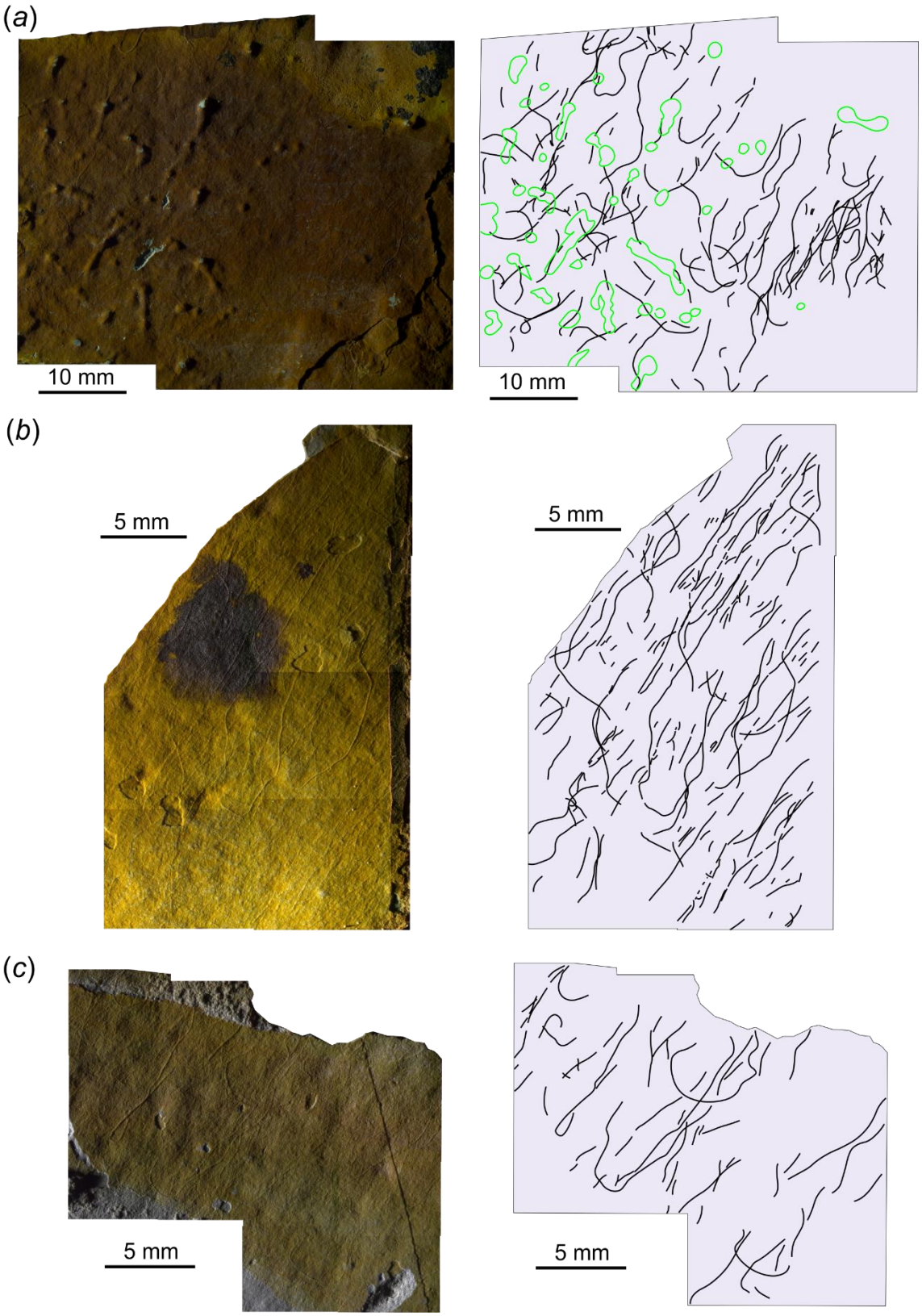
B.B-K. and P.S.G.P. designed the study; B.B-K., P.S.G.P. and A.L.Z.R. collected the material; B.B-K. and G.E.B.B carried out the morphological description and database compilation; all authors contributed to the interpretations of the results. B.B-K. drafted the manuscript, with significant contributions from M.L., P.S.G.P., A.E.A., G.M.E.M.P., G.L.O, and G.E.B.B.; all authors gave final approval for publication.

**Funding.** This work was funded by the Fundação de Amparo à Pesquisa do Estado de São Paulo under the proposal grants 2016/01827-4 and 2018/21886-0.

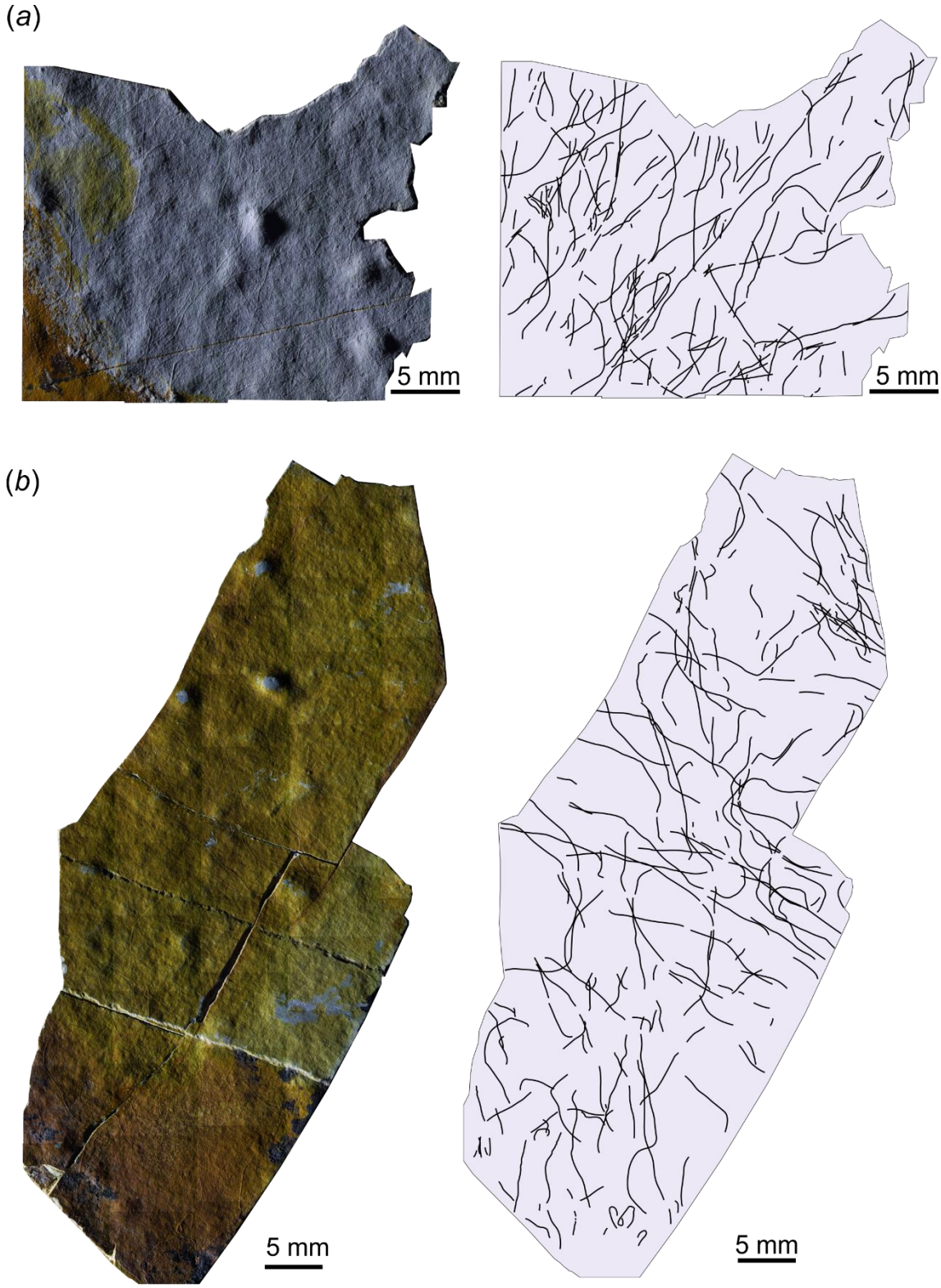
**Acknowledgements.** The authors thank the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP - Grant 2016/01827-4 and Grant 2018/21886-0), the Programa de Pós-Graduação em Ecologia e Recursos Naturais (PPGERN – UFSCar), and the Programa de Pós-Graduação em Geologia (PPGeo – UNISINOS). This work was also supported by La Région Nouvelle Aquitaine. B.B-K. and PSGP would like to thank for the support from the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq). The artistic representation was made by Júlia Soares d'Oliveira.

## Supplementary Information

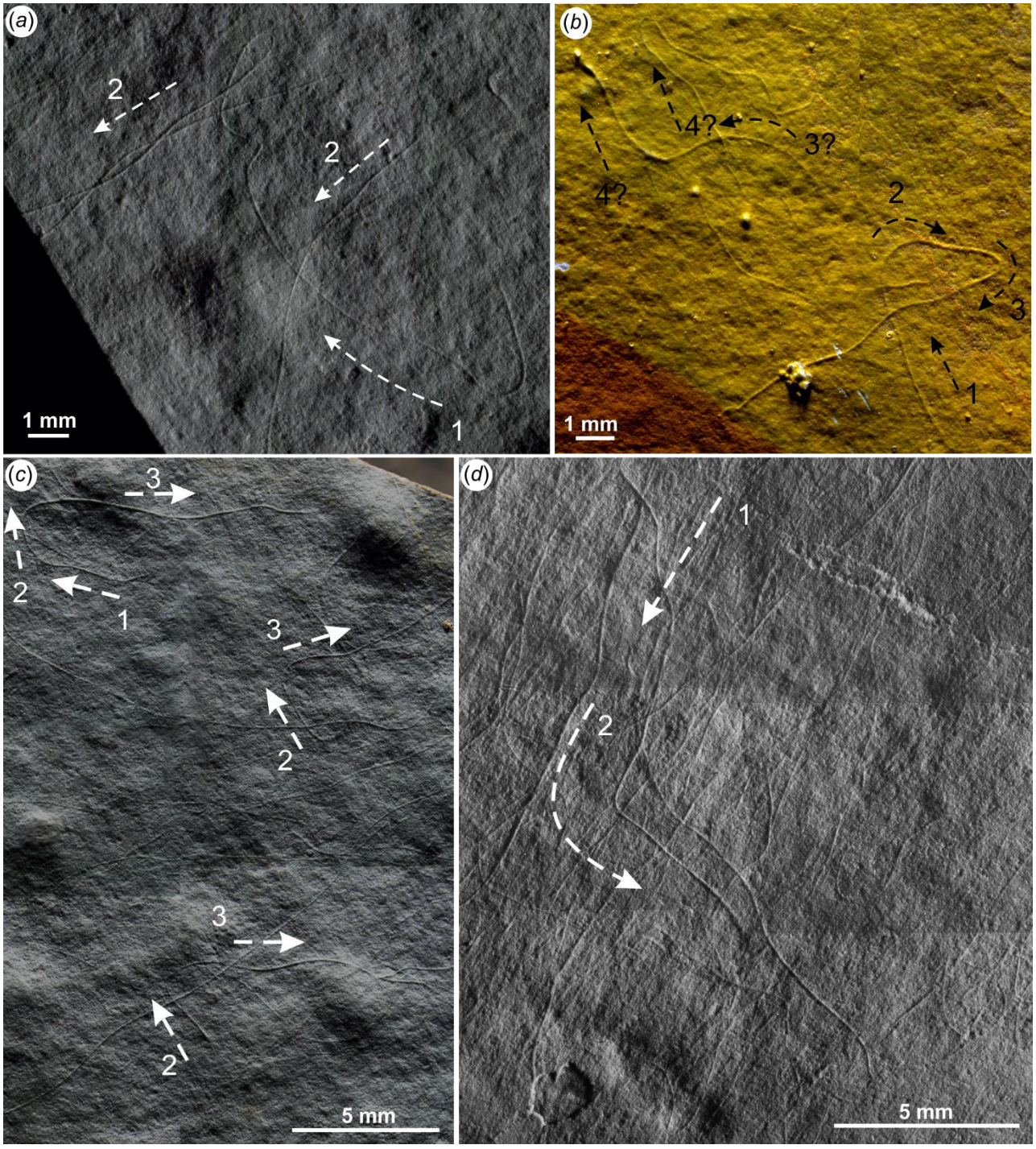

**Supplementary Figure 1**. Schematic drawing of a densely populated surface. Note the general orientation of the filaments towards the upper-left and bottom-right.



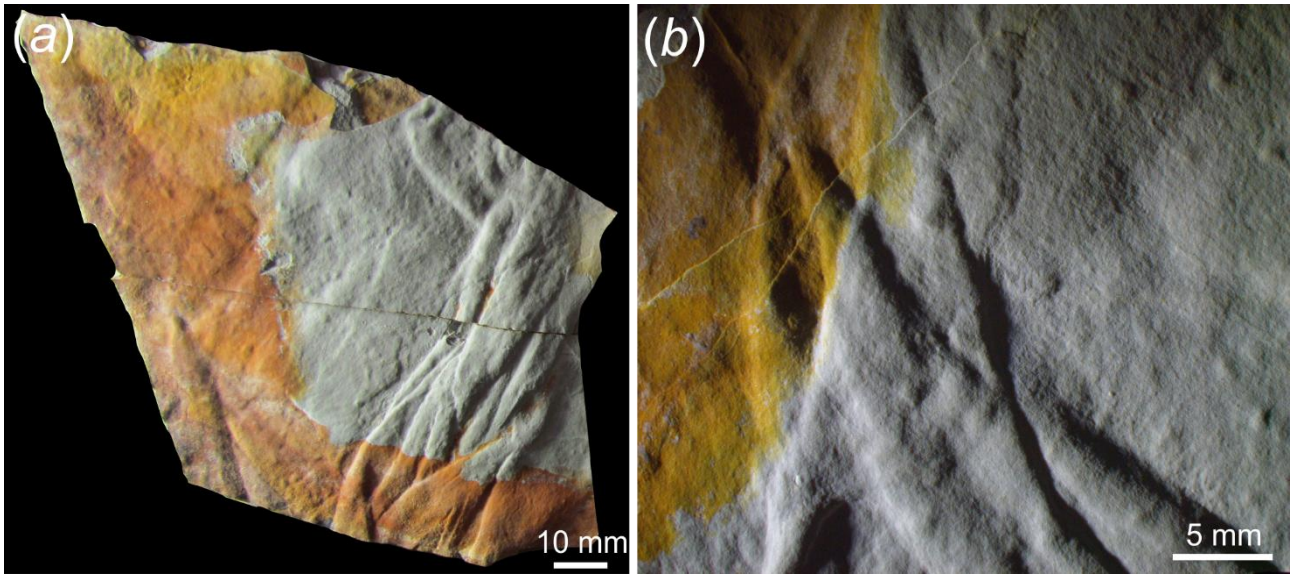

**Supplementary Figure 2**. Imaging of the entire surface with visible filaments and their respective schematic drawing. Note the association of the filaments with the pustular surface in (a), and several oriented individuals in (b) and (c).



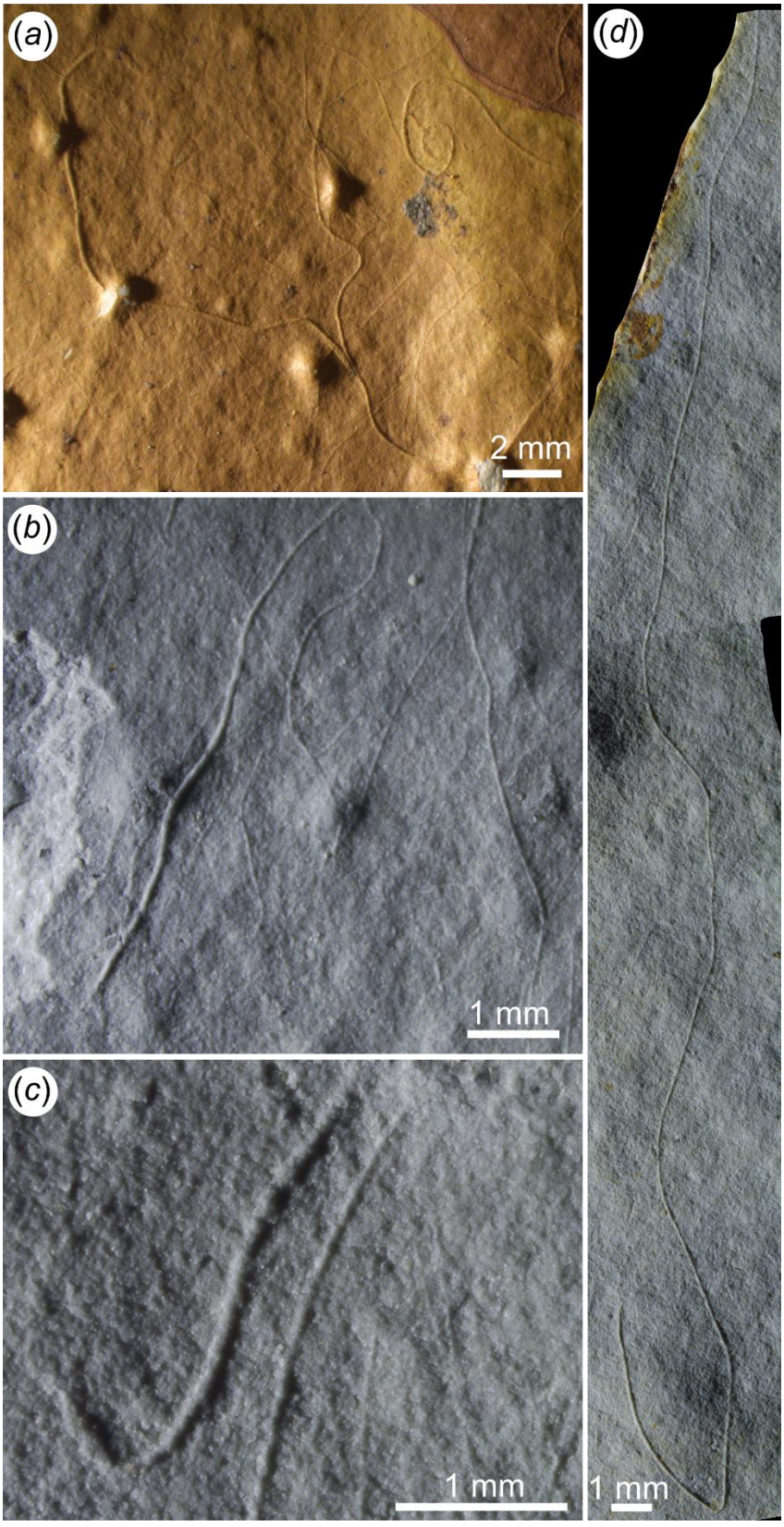

**Supplementary Figure 3**. Oriented specimens associated with pustular surface.




**Supplementary Figure 4**. Sequentially oriented filaments. The order of orientation can be revealed by the pattern of superposition of the filaments.




**Supplementary Figure 5**. Rolled up microbial mats (positive epirelief) with highly folded morphologies.




**Supplementary Figure 6**. Some of the largest filaments (in width [a,b,c,] and length [d]) recorded for the Itajaí Basin.

# 5 ARTICLE THREE

## The role of volcanic-derived clays in the preservation of Ediacaran biota


### Abstract

The early evolution of metazoans has been reconstructed by studies on exceptionally preserved molds in siliciclastic rocks from the Ediacaran Period. However, there remains considerable controversy regarding the formation mechanisms of this unusual 'Ediacaran-style' preservation. Proposed hypotheses usually include early authigenesis of minerals, but evidences for this are scarce. In a recently discovered Ediacaran biota in Brazil, we show that the moldic preservation can also be related to clay mineral authigenesis. Specifically, these clays originated from microbial alteration of original pyroclastic sediments, leading to early illitization and morphological templating of the fossiliferous surfaces on an almost cellular level. Such high-fidelity preservation was made possible by the rapid burial during volcanic events and the in-situ templating of tissue by clays via microbially-mediated biomineralization. This newly described *Lagerstätten* demonstrates that a number of minerals can facilitate preservation, and that perhaps 'Ediacaran-style' preservation is in and of itself only unique by the age of the specific fossils preserved, not the mechanisms.


### Introduction

The typical moldic preservation of soft-bodied organisms in the Ediacaran Period (635–539 Ma) (Gehling, 1999; Tarhan et al., 2016; Liu, 2016; Bobrovskiy et al., 2019b), in particular the positive epirelief type where the fossils protrude up from the surface (Bobrovskiy et al., 2019b), has few parallels in other periods of geologic time, hence the term "Ediacaran-style preservation." One explanation points to rheological differences amongst the sediments(Wade, 1968), a hypothesis that has received recent support (Bobrovskiy et al., 2019b). Gehling (1999) also proposed the so-called 'death-mask' model for this preservation, in which microbial mats stabilized the sediments and produced a veneer of authigenic pyrite ($FeS_2$) that replicated the morphology of the organisms. Evidence in favor of this hypothesis comes from the presence of iron oxide and pyrite concentrations along fossiliferous bedding planes in certain localities (Liu, 2016; Liu et al., 2019). Other hypotheses include episodic event

deposition (Seilacher, 1992), early cementation by quartz ($SiO_2$) in silica-rich oceans (Tarhan et al., 2016), and burial by volcanic ash – the so-called “Conception-style” preservation (Narbonne, 2005).

It is similarly possible that multiple mechanisms could produce this type of moldic fossilization and/or that taphonomic factors varied according to the geologic setting. In this regard, the Itajaí Basin (da Silva et al., 2002; Guadagnin et al., 2010; Basei et al., 2011) (ca. 563 Ma, Brazil) appears to be a promising locality in which to study the possible mechanisms of preservation operating during the Ediacaran Period due to the high-fidelity preservation of the fossils. In a recent paper, Becker-Kerber et al.(Becker-Kerber et al., 2020) described the Itajaí biota, reporting the presence of *Palaeopascichnus*, discoidal forms, microbial filaments, Arumberia and fossilized microbial tufts. In this work, we apply a diverse array of techniques to address the fossilization processes of this new Ediacaran locality. More specifically, we demonstrate the close association of body fossils and microbial mats with volcanic sediments. We then provide a mechanism for the morphological preservation of tissue on an almost cellular level that includes the rapid formation of authigenic clays during early diagenesis as a result of the alteration of volcanic materials and microbial activity.

**Results**

The Itajaí biota is composed of the well-known chambered taxon *Palaeopascichnus*, the discoidal forms *Aspidella* and *Nimbia*, and micron-sized microbial filaments (Becker-Kerber et al., 2020) (Fig. 1). Well-preserved reticulated and Arumberia-type microbial mats have also been observed (Fig. 1b). We detected three modes of preservation: (1) impressions in positive epirelief (*Palaeopascichnus*, *Aspidella*, and microbial filaments); (2) impressions in negative epirelief (*Aspidella*); and (3) three-dimensionally preserved microbial mats (Fig. 1). Investigations by microtomography (µ-CT) corroborated the moldic preservation of the filaments as well as the unusual 3D nature of the microbial mats (Supplementary Fig. 1, and Movie 1). Remarkably, very small filaments (c. 30 µm in width) are preserved as impressions, and some individuals even seem to bear cellular structures (Fig. 1e). This minute detail indicates a level of morphological retention in molds that is unprecedented in the fossil record because filamentous microfossils with cellular structures are usually permineralized or occur as palynomorphs (Schopf and Klein, 1992). Additionally, to our knowledge, this is the first

case of three-dimensional preservation of microbial mats in siliciclastic settings in the geological record.

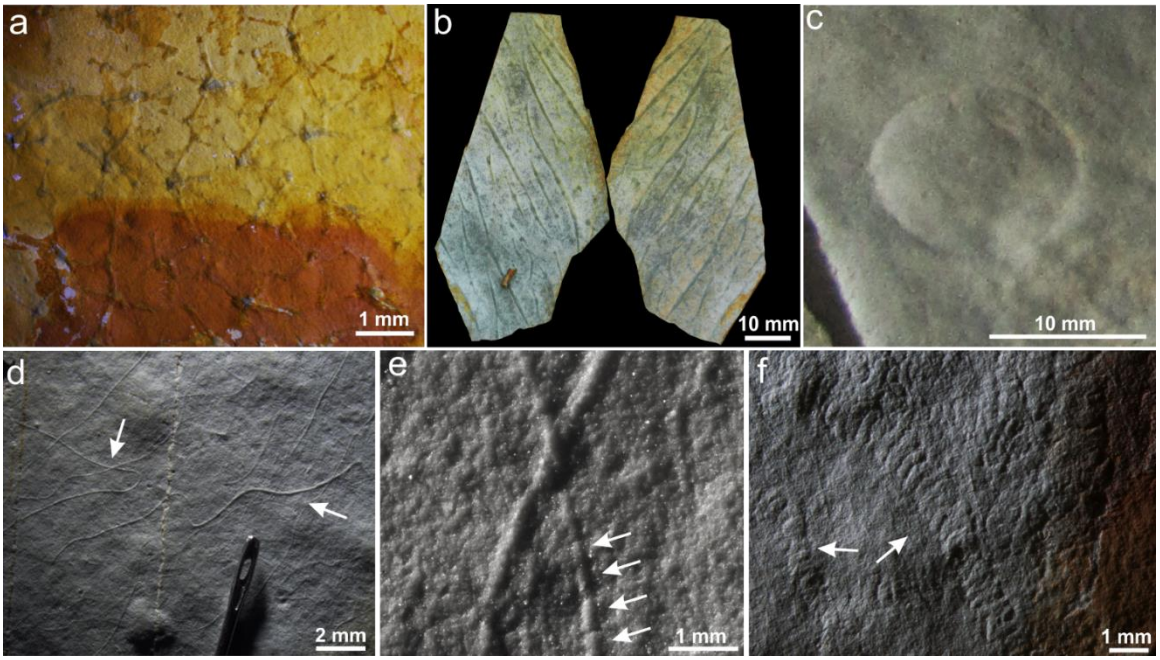



**Figure 1**. **Typical fossils and preservation styles in the Itajaí Basin**. **(a)** Three-dimensionally preserved tufted microbial mats (CAP-879). **(b)** 3D Arumberia-type microbial mats (CAP-880). **(c)** *Aspidella* in positive hyporelief (CAP-549). **(d)** Microbial filaments in positive epirelief (CAP-881). **(e)** Exquisite preservation of microbial filaments bearing cellular structures (arrows) (CAP-866). **(f)** *Palaeopascichnus* in positive epirelief.

The fossiliferous levels mostly occur in pale-gray millimeter-scale rhythmites of mud and silt that were deposited in an upper slope setting subjected to rhyolitic volcaniclastic input (Supplementary Text 1, Supplementary Figs. 2, 3). These layers additionally display abundant evidence of microbial mat development. The fossil impressions are located in clay-rich laminations characterized by opaque and microcrystalline clay minerals (Supplementary Fig. 4). This material also forms the unique three-dimensional microbial mats (Fig. 1d–e, Supplementary Figs. 4, 5). Exquisitely preserved microbial mats are also present in distal delta-front deposits (e.g., Arumberia; Supplementary Fig. 2) associated with reworked volcaniclasts and impressions of *Nimbia*.

The upper slope fossiliferous beds, which yielded the majority of samples, are represented by ash-fall pyroclasts, including elongate, cuspate, angular and blocky devitrified vitric clasts; euhedral phenocrysts (some broken); accretionary pellets

(sensu Brown et al. (2012); ash clusters; and coated particles (Fig. 2, Supplementary Figs. 6, 7g–j). Coarse-grained silt laminae interbedded with the fossiliferous horizons also contain volcaniclasts, which likely represent a mix of primary and reworked ash-fall deposits (Supplementary Figs. 2, 7a–f, k–o). These clasts exhibit devitrification features with formation of clay minerals (Supplementary Fig. 8), as well as clay rims and fluid and/or melt inclusions (Supplementary Figs. 7n–o, 8g).

Fine layers of altered ash were observed directly covering well-preserved microbial filaments (Fig. 2d, Supplementary Fig. 6). In thin section, these surfaces are characterized by localized concentrations of very fine clays (Supplementary Fig. 6g–h). In some layers, early-formed fractures developed mainly following these bedding surfaces. These layers were filled by fibrous radial micaceous crystallites (sericite) and later by quartz (Fig. 2l–m, Supplementary Fig. 6i–l). The formation of this fibrous sericite seems to have occurred before the lithification of the deposits given their molding relationship with the surrounding sediments (Fig. 2m). The early-filled fractures are observed in some instances to crosscut the clay-mineralized fossiliferous surfaces, implying an early origin for the fossil-bearing clays.

Other outcrops, mostly restricted to the southwestern portion of the basin, also show evidence of volcanic activity. In particular, abundant and well-preserved glass shards and glass spheres (i.e., acneliths) occurring in silicified tuffites in one fossiliferous outcrop display devitrification to clay minerals similar to those described above (Fig. 2n, o, Supplementary Fig. 9). It is interesting to note that these acneliths have peculiar morphologies with spheroidal, ellipsoidal and tear-drop shapes, many bearing spiny projections that resemble modern Pelle’s tears(Heiken, 1972). This configuration indicates that the Itajaí Basin also had pyroclastic sediments derived from basaltic volcanism.

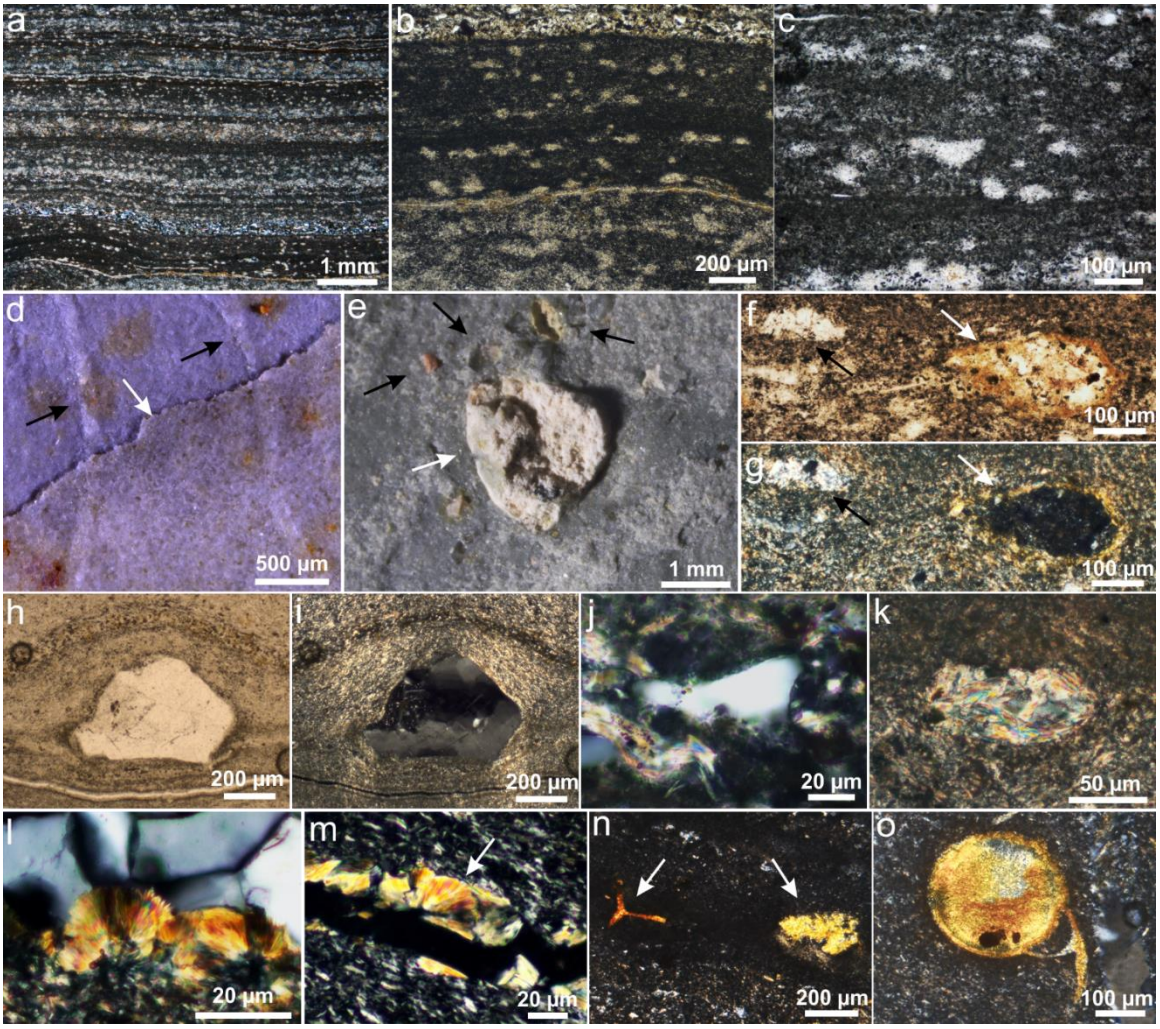



**Figure 2. Pyroclasts from the fossiliferous horizons of the Itajaí Basin. (a)** Vertical thin section through different clay (darker) and silt (whitish) laminations with several devitrified pyroclasts (small scattered white clasts); crossed nicols. **(b)** Closer view of the same texture, with devitrified pyroclasts following the bedding plane; plane-polarized light. **(c)** Pyroclasts devitrified to microcrystalline quartz. **(d)** Microbial filaments covered by a thin layer of altered ash. **(e)** Accretionary pellet (white arrow) and scattered phenocrysts (black arrows). **(f-g)** Thin sections of a small accretionary pellet (white arrow) and devitrified pyroclast (black arrow); plane-polarized light (f) and crossed nicols (g). **(h-i)** Large lithic phenocryst with an equant shape. **(j)** Cuspate shard, crossed nicols. **(k)** Euhedral clast devitrified to sericite. **(l-m)** Fibrous radial sericite in early-formed fractures. Note the molding relationship (m) with the host rock. **(n-o)** Devitrified glass shards (n) and glass spheres (o) in cherty tuffite.

X-ray diffraction (XRD) patterns and mid-infrared (MIR) and near-infrared (NIR) spectra further reveal that the fossil-bearing clays (clay-rich fossiliferous surfaces and

clay-mineralized microbial mats; hereafter FBCs) are mineralogically similar to the volcanic sediments (volcaniclastic laminae - VL, tuffs and tuffites) but differ from other facies throughout the basin that do not show abundant volcaniclasts or clay mineralized fossils (see Supplementary Text 2, Figs. 10–19, Dataset 1). The FBCs and clays from the volcanic-derived sediments show a predominance of illite (1M polytype) and ordered illite-smectite mixed-layer minerals (R3 I–S MLMs), as suggested by the shoulder on the left side of the illite peak (at 10 Å) and further confirmed by NEWMOD modelling (Supplementary Figs. 14, 15). At higher resolution, the XRD data show that the FBCs exhibit a higher proportion of illite than the clays from the adjacent VL of the same beds, as well as from the tuffs and tuffites (Supplementary Figs. 13, 14). By contrast, the clay assemblages from facies with no fossil-bearing clays are represented by smectite and randomly ordered R0 I/S MLMs (Fig. 3h, Extended Text 2, and Supplementary Figs. 10–19).

Interestingly, in the MIR region between 3000 and 2800 $cm^{-1}$, spectra from both the FBCs and the volcanic material show higher intensities in the absorption bands related to the $CH_3$ and $CH_2$ stretching vibrations of aliphatic compounds than those found in samples without fossil-bearing authigenic clays (Supplementary Fig. 18). This finding reinforces the interpretation that volcanic sediments played a role in improving the preservation of the remaining organic material.

In agreement with the results above, scanning electron microscopy with energy dispersive X-ray spectrometry (SEM-EDS) and synchrotron radiation micro-X-ray fluorescence spectroscopy (SR-µXRF) analyses showed that the FBCs have high concentrations of K, Al, Fe, Ti, and Mg (Fig. 3), while the host rock contains high concentrations of elements related to the nature of the clasts and cements (e.g., Si, Na, and Fe). The higher concentrations of Al and K, and slightly higher concentrations of Mg in the FBCs than in the host rock, are related to their illitic composition, as confirmed by the oxide weight% results of EDS point analyses (Dataset 2). These illite-rich crystals have the following average composition: $(Si_{3.56},Al_{0.44})O_{10}(Al_{1.63},Mg_{0.11},Fe_{0.20})(OH)_2(K_{0.61},Na_{0.01})$. Raman spectroscopy of the 3D clay-mineralized microbial mats additionally reveals the characteristic peaks of illite (ca. 200 $cm^{-1}$, 264 $cm^{-1}$, 396 $cm^{-1}$, 464 $cm^{-1}$, and 703 $cm^{-1}$) (Fig. 3e, Dataset 3). The results from the fitting of several spectra demonstrate that illite is indeed more concentrated in the FBCs than the cement/matrix (Supplementary Text 3, Supplementary Fig. 21).

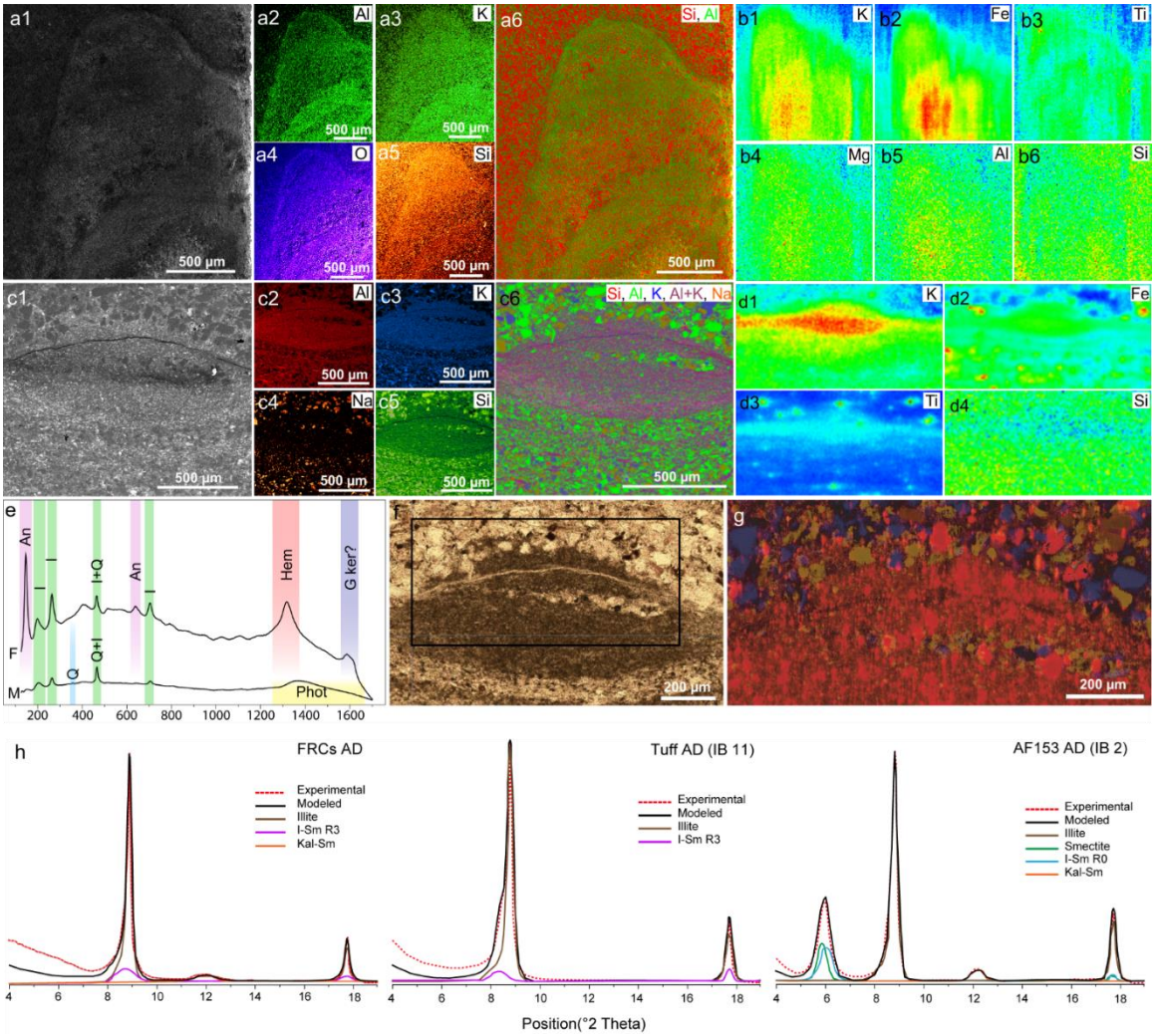



**Figure 3**. **Geochemical analyses of the fossil-related clays (FBCs) in three-dimensionally preserved microbial mats**. **(a)** SEM image and EDS maps of a region diagonally crosscutting a 3D preserved tufted microbial mat (see Supplementary Fig. 5), highlighting the concentration of Al and K in the biogenic structure. **(b)** SR-µXRF maps of the same region, showing increased intensities of K, Fe, Ti, Mg and Al in the fossil-bearing clays. **(c)** SEM image and EDS maps of a cross-section through a 3D preserved Arumberia-type microbial mat (see Supplementary Fig. 5), revealing relatively higher intensities of Al and K in the fossil. **(d)** SR-µXRF of the same region as in (c), showing enrichments and spatial relations of K, Fe and Ti with the microbial mat. **(e)** Representative Raman spectra of FBCs (F) and rock matrix (M). An – anatase, I – illite, Q – quartz, Hem – disordered hematite, G ker– possible G band of kerogen, Phot – artifact of photoluminescence from the glass. **(f-g)** Raman mapping of anatase, quartz and plagioclase of the Arumberia sample. Note the concentration of disseminated and fine-grained anatase in the fossil. **(h)** XRD patterns (air-dried) and

NEWMOD modeling of the FBCs, the tuff sample, and a distal delta-front mudstone sample.

Raman spectroscopy reveals that anatase ($TiO_2$) is the Ti-bearing phase in the 3D clay mineralized microbial mats (Fig. 3e–g, Dataset 4). Anatase is formed of micrometer- to submicrometer-sized crystals (Fig. 3g, Supplementary Fig. 22). Anatase is especially concentrated in the microbial mats, while the matrix also contains a high proportion of another $TiO_2$ mineral, rutile (Supplementary Text 3, Dataset 3).

**Discussion**

The alteration of unstable volcanic glass is well known to promote the formation of new silicate phases(Fisher and Schmincke, 1984; Kawano and Tomita, 1992, 1997, 2002; Ghiara et al., 1993; Kawano et al., 1997; De La Fuente et al., 2000; Konhauser et al., 2002). Their instability is due to nonbridging silicate sites, which allow easy alteration at low temperatures(Kawano et al., 1997). In fact, both experimental and field-based studies have shown the formation of smectite and R0 I-S MLMs from the alteration of volcanic glass occurring at low temperature(Kawano and Tomita, 1992, 1997; Ghiara et al., 1993; De La Fuente et al., 2000). For instance, Kawano & Tomita(Kawano and Tomita, 2002) demonstrated that bacterially influenced alteration of pyroclastic sediments can lead to smectite formation through an allophane precursor, while Konhauser et al.(Konhauser et al., 2002) showed the formation of smectite directly on the cell surfaces of bacteria colonizing basaltic tephra. According to our results, in the FBCs and volcanic sediments of the Itajaí Basin, smectite and/or I-S MLMs were likely the mineral phases derived from the alteration of volcanic sediments. In the Itajaí Basin, the alteration of volcanic sediments, supported by microbial activity, resulted in microenvironments enriched in cations, such as $K^+$, $Al^{+3}$, and $Na^+$, and then to the precipitation of newly formed clay minerals.

The higher amount of illite in the FBCs than in the adjacent VL and tuffs suggests a link between the presence and activity of microbial communities, and the processes of early diagenetic illitization that resulted in fossil preservation. It is hypothesized here that this higher illitization could then have occurred via two mechanisms: [1] further enrichment in $K^+$ resulting from microbial metabolism and/or [2] dissimilatory iron reduction (DIR) of $Fe^{3+}$ in smectite. The former hypothesis is similar to the one proposed for the microbial mats of the Paleoproterozoic Francevillian

Group (Aubineau et al., 2019), where the presence and/or metabolism of ancient microbial mats served as the source of $K^+$ for the illitization of these microbially related surfaces. Unlike the Francevillian case, in the Itajaí Basin, K-feldspar grains are common in volcaniclastic sediments and likely contributed to posterior diagenetic illitization. However, their presence does not account for the higher illitization of the FBCs than the clays in the VL and tuffs. The second mechanism (DIR) is related to the dissolution of smectite layers during the illitization process. This process could also account for the presence of disordered hematite in the FBCs (see Kim (2012). Furthermore, Zhang et al. (2007) demonstrated that illitization by DIR can be enhanced by an external supply of Al and K, which in the Itajaí Basin could have come from volcaniclastic material. The release of dissolved iron may have also contributed to the adsorption of this element by the extracellular surfaces of bacterial cells, as observed in modern examples (Konhauser et al., 1993). This process can subsequently result in the formation of sites prone to the nucleation of clay mineral phases (Konhauser et al., 1993, 1998; Konhauser and Urrutia, 1999). Several other studies also supported the role of microbes and extracellular polymeric substances (EPS) in providing sites for the nucleation and growth of clay and silicate phases (Ferris et al., 1987, 1991; Tazaki, 1997; Ueshima and Tazaki, 2001).

Interestingly, the enrichment in anatase (as well as disordered hematite, $Fe_2O_3$ – Fig. 3e) inside the microbial mats suggests another role for the microbial metabolism in defining the microenvironmental conditions. Studies with modern cases have shown that Fe and Ti can be released in the microenvironment through the bioleaching of ilmenite ($FeTiO_3$) by Fe(II)-oxidizing and/or iron-scavenging bacteria (i.e., those that produce siderophores) (Navarrete et al., 2013), thus creating conditions for the precipitation of new phases, such as anatase. Furthermore, experiments with photosynthetic microbial mats have shown the influence of biological activity on the precipitation of anatase when ilmenite was added to the medium (Bower et al., 2015, 2017). In the Itajaí Basin, Fe-Ti oxide grains (e.g., ilmenite and titanomagnetite - now altered to leucoxene; Supplementary Fig. 22) are common in the volcaniclastic sediments, and are a likely source of anatase and Fe enrichment in the ancient mats.

We hypothesize that a combination of abundant and easily-altered volcanic particles - in addition to microbial activity - were the essential conditions necessary for the preservation of the Itajaí biota. This complex interplay between volcanic sediments and microbial activity culminated in the formation of abundant early diagenetic clays

(Fig. 4), resulting in templating the fossil-bearing surfaces with clay precipitates, and preserving the external morphologies of macro-organisms and microbial filaments. In this sense, the Itajaí fossilization pathway could be regarded as a connecting model between the death-mask and the conception-style hypotheses, where both microbial and volcanic activity were essential to the 'Ediacaran-style' fossilization by authigenic minerals.

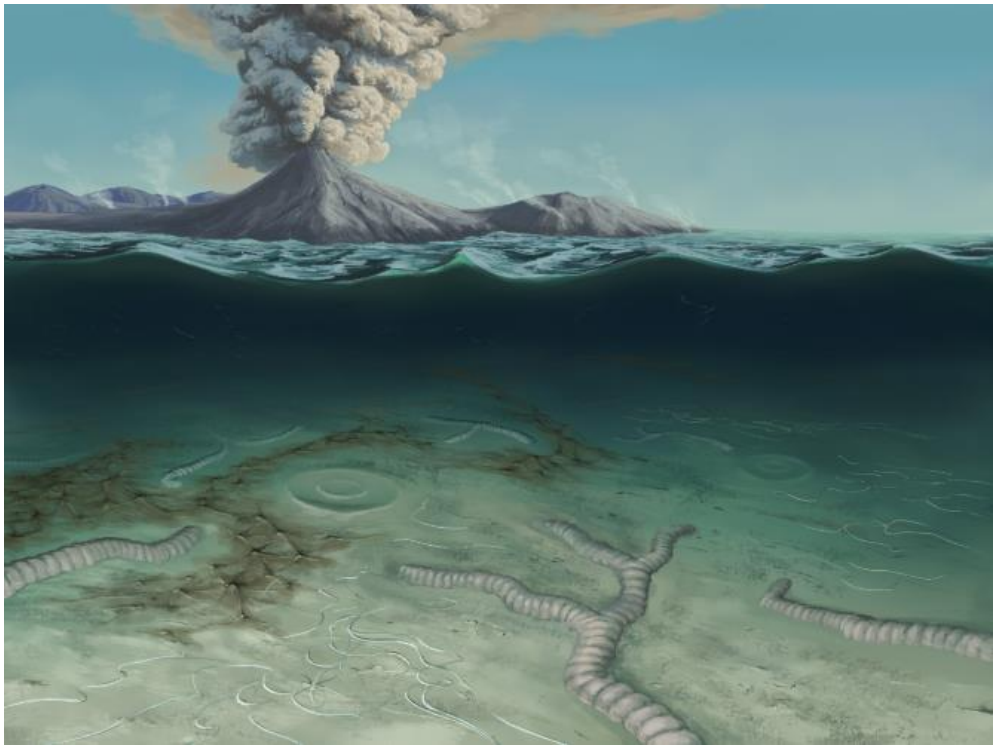


**Figure 4**. Artistic representation of the volcanic and microbial influences on the preservation of Itajaí organisms.

The role of volcanic material in the preservation of certain Ediacaran assemblages has been previously proposed for the conception-style preservation (Narbonne, 2005). However, details explaining this mechanism have not been provided to support this hypothesis, and until now, no authigenic minerals have been associated with this model. In this sense, without further evidence, one could consider the 'conception-style' preservation observed in Newfoundland as resulting simply from event deposition, as previously noted (Seilacher, 1992). Moreover, recent studies have even extended the death-mask model to these deposits, where pyritization would have played a major role in the moldic fossilization (Liu, 2016). Our work shows that, at least for some basins, the fossilization of the Ediacaran macroscopic communities was the result of the interconnected processes related to volcanic and microbial activity.

Volcanic activity has often been considered one of the main causes of biotic events during the history of life on Earth, and here we demonstrated unequivocally that volcanism also played an important role in preserving the information of ancient ecosystems. Other examples are also known from the fossil record (Jefferson, 1982; Hay, 1986; Scott, 1990; Briggs et al., 1996; Orr et al., 2000; Sutton et al., 2005; Jiang et al., 2011; Cantrill et al., 2013) and show that volcanism was not only important for exceptional preservation throughout the geologic record but also diverse in terms of processes and composition of the precursor material.

## Materials and Methods

**Macroscopic and petrographic investigation**. Macroscopic features of hand samples were analyzed using a Stereomicroscope ZEISS SteREO Discovery V20 coupled with an Axiocam camera at the Laboratório de Ecologia at the Universidade Federal de Mato Grosso do Sul. The preparation of thin sections was carried out in the Programa de Pós-Graduação em Geologia da Universidade do Vale do Rio dos Sinos (UNISINOS – São Leopoldo). Approximately 119 thin sections of the fossiliferous levels, tuffites, tuffs, and other facies were prepared in order to compare the petrographic data with the mineralogical results from the other techniques. Representative thin sections were polished for a better characterization of the volcaniclasts and devitrification features. We used Zeiss microscopes at the UNINOS and Université de Poitiers (France).

**X-ray diffraction and NEWMOD modeling**. Whole-rock powder and clay mineral fractions (<2 μm) from 24 samples were analyzed with a Panalytical Xpert Pro diffractometer at the University of Poitiers using Cu (Kα = 1.541874 Å) radiation, with the following configuration: Xccelerator detector; geometry □/□ (Bragg-Brentano) ; goniometer of 240 mm radius; wavelength filter of Ni (0.3 mm thick); anti-divergence slit of 1/8 °2□, anti-diffusion slit of ¼°2□; mask of 10 mm in diameter; soller slit of 0.04 rd spacing; and fixed sample holder. The analyses were performed with a voltage of 40 kV and current of 40 mA in the angular range of 2 to 65°2□ (powder) and from 2 to 35º 2□ (oriented preparation).

Twenty-two samples originated from different levels (fossiliferous and nonfossiliferous) throughout the basin, while the fossil clays and the intercalated coarse-grained laminae were carefully selected and removed from the fossiliferous

beds. These fossiliferous samples were first prepared using air abrasive processes to grossly clean and remove surrounding matrix from the 3D clay-mineralized microbial mats. Then, we extracted the clays from the selected structures and laminae (fossilized microbial mats and intercalated coarse-grained laminae) under a stereomicroscope using a scalpel. All samples were ground in a mortar and separated for powder analysis. Later, we extracted the clay size fraction (<2 μm) for the oriented preparation. These clay size fractions were then Ca saturated and mounted on glass slides for analysis in air-dried ethylene glycol and after thermal treatment (i.e., 350ºC and 550ºC).

For the characterization of the I–S MLMs we used NEWMOD simulation to model the Reichweite ordering parameter (R), which can range from randomly interstratified (R = 0) to long-range ordered MLMs (R = 1, 2, and 3).

**Scanning electron microscopy**. We used a Quanta 650FEG and FEI Inspect F50 microscopes (project SEM-21836 and SEM-23684) at the Brazilian National Laboratory of Nanotechnology (LNNano/CNPEM) and a JEOL JSM IT500 scanning electron microscope, equipped with secondary electron, backscatter electron detectors and coupled with a Bruker lynxeye Energy Dispersive X-ray Spectrometer (EDX) at the IC2MP laboratory of the Université de Poitiers. Analyses were conducted in high-vacuum mode and with a current tension of 15 Kv. Quantitative SEM point analyses were performed for clay minerals and the corresponding structural formulas were calculated from the total oxides weight percent.

**SR-μXRF**. The SR-μXRF investigation was performed at the Brazilian Synchrotron Light Laboratory (LNLS) under proposals 20171031 and 20180327. We used polychromatic excitation in microbeam mode and filtering with Fe foils for the measurements. For the FlyScan mode we applied 500 ms of count time per point. For data treatment we used the PyMCA software.

**Raman spectroscopy**. We used a Renishaw InVia microRaman with 785 nm lasers and 17 mW total power (attenuated). The spectra acquisition for all the points in the clays was performed using the same configuration: 785 nm laser; 1s of exposure time; 100 accumulations; laser power of 50%; static acquisition with center in 750; and objective of 100x. This approach yielded robust data for the statistical comparisons of

the fossil clays, matrix and detrital micas. These spectra were obtained in two different time periods and thus compared separately regarding peak position since small variations can occur in the equipment. Both groups of data presented the same pattern of results (see Supplementary Fig. 2). The Raman spectra of the Ti-oxides were realized using the same configuration, with the exception of laser power (5% in this case). Baseline subtraction and fitting were performed using WiRE 4.1. Raman maps were obtained using the streamline method.

**Mid-infrared and near-infrared (MIR, NIR)**. We used the clay fractions of the samples for the MIR and NIR investigation. For the MIR, we prepared KBr discs with 1 mg of sample and 149 mg of KBr. The mixture was ground and then pressed under 8 tons during 5 minutes to create the discs. Then, the samples were analyzed by a Nicolet iS50 Fourier transform infrared spectrometer using a DTGS KBr detector with a resolution of 4 $cm^{-1}$ and accumulation of 100 scans in the range of 4000-400 $cm^{-1}$. The NIR was performed in a Nicolet 6700 Fourier transform infrared spectrometer. All spectra were processed using the OMNIC software.

**µ-CT**. The X-ray microtomographic analysis was performed at the PLATINA platform of the IC2MP (University of Poitiers) with the RX-Solutions EasyTom XL Duo device. We used a microfocus X-ray source (Hamamatsu L8121-03) coupled with a flat panel imager (Varian PaxScan 2520 DX). The acquisition parameters were as follows: 120 kV voltage, 200 µA current, 1 mm Al filter, stack acquisition with 2880 projections in 2 turns to acquire the whole sample, 8 frames per second, average of 10 frames per projection, with anti-ring shift procedure and a spatial resolution of 18.3 µm. The data reconstructions were computed using XAct (RX Solutions) and virtual sections: 3D rendering and movies were produced using AVIZO v.2019.2 (Thermo FisherTM-FEI). X-ray microtomography was also performed at the Brazilian Synchrotron Light Laboratory (LNLS) in the IMX beamline in the energy range of 5 keV to 20 keV with average flux of 8.1 x 1013 photons/s/$mm^2$ using the white beam. We used a Si filter of 350 µm. The sample was rotated in 180º, and the time of exposition varied according to the intensity of the transmitted beam. The images were reconstructed with the pyRaft62 algorithm. We then processed the reconstructed images using the software AMIRA 6.2 and AVIZO 9.1.

**Acknowledgments**

The authors thank the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP - Grant 2016/01827-4 and Grant 2018/21886-0), the Programa de Pós-Graduação em Ecologia e Recursos Naturais (PPGERN – UFSCar), and the Programa de Pós-Graduação em geologia (PPGeo – UNISINOS). This work was also supported by La Région Nouvelle Aquitaine. BB-K and PSGP thanks the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for the support. We thank the Brazilian Synchrotron Light Laboratory (LNLS-CNPEM) and the Brazilian Nanotechnology National Laboratory (LNNAno-CNEPM), which provided the facilities for the SR-µXRF (proposals 20170438; 20171031; 20180327), SEM/EDS (proposals 21836 and 23684) and µ-CT (IMX proposal 20180137) analyses. The Laboratório de Preparação de Lâminas Delgadas of UNISINOS provided the thin section preparation. The authors are also grateful to Laboratório de Ecologia (UFMS), Alan Eriksson and Alêny Lopes Francisco Batista for providing access to Stereomicroscope SteREO Discovery V20. We are thankful for the scientific advice from H-U Schminke. We acknowledge J. Brunet, B. Gregoire, C. Laforest, and C. Boissard for all the support during the analyses at the University of Poitiers. The artistic reconstruction was made by J. S. d'Oliveira.

**Author Contributions**

BBK, MLAFP and AEA conceived the project. BBK wrote the article with significant contributions from all authors. BBK and CF conducted the clay analyses; interpretations of these results were made by BBK, AEA, KK, AAE, CF, and AMe. AMa performed the µCT analyses and reconstructions at the Université of Poitiers and BBK carried out the µCT analyses at LNLS. AAE performed the structural formula calculations and the Newmod modelling. Field work was performed by BBK, MLAFP, PSGP, ALZR, and TRF. Geologic interpretations were performed by PSGP. Petrographic study was carried out by BBK, with contribution of PSGP and TRF. SR-µXRF was conducted by BBK, GMEMP, and GLO. SEM analyses were performed by BBK, GMEMP and GLO. Raman investigations of the clays were made by BBK, and Raman analyses of the Ti-oxides were realized by PBK and DG.

**Competing Interests statement**

The authors declare no competing interest.

# Extended Data for “The role of volcanic-derived clays in the preservation of Ediacaran biota”

## Supplementary Text 1 – Geologic setting

The Itajaí Group is interpreted as a foreland basin composed of four or five depositional sequences with occasional volcaniclastic input (Rostirolla, 1991; Rostirolla et al., 1992, 1999; Guadagnin et al., 2010; Basei et al., 2011) (DS1–5) (Supplementary Fig. 2, 3). However, there remains controversies regarding the stratigraphic position of the possible DS 5, and for that reason it was excluded from our generalized stratigraphic column (Supplementary Fig. 2). Some authors interpret the DS5 deposits as a repetition of the previous units due to overthrusting. Zircon radiometric dating of tuff levels of the DS1 revealed sedimentation ages of 563± 3 Ma (Becker-Kerber et al., 2020), agreeing with previous reported ranges for the deposition of the Itajaí Basin (572-549 Ma; see ref (Guadagnin et al., 2010))

At the base, the DS 1 is characterized by alluvial deposits grading to deltaic-shallow marine settings. The overlying DS2 is composed by turbidite deposits, and upsection by upper-slope sediments. DS3 is defined mainly by shallow marine and prodelta deposits. DS4 is also characterized by shallow marine settings, but in this case with more influence of fluvial and proximal delta sediments. The possible DS5 repeats the facies observed in the previous sequences, being composed of turbidites and deltaic deposits. Further discussion on the stratigraphy, depositional environments and tectonic setting of the basin can be found in Rostirolla (Rostirolla, 1991), Rostirolla et al. (Rostirolla et al., 1992), Gresse et al. (Gresse et al., 1996), Fonseca (Fonseca, 2004), Teixeira et al. (Teixeira et al., 2004), Guadagnin (Guadagnin et al., 2010), Basei et al. (Basei et al., 2011). Here we follow the approach of Becker-Kerber et al. (Becker-Kerber et al., 2020) in adapting the depositional sequences defined by Fonseca (Fonseca, 2004) and Teixeira et al. (Teixeira et al., 2004).

## Supplementary Text 2 – Clay assemblage of the Itajaí Basin

XRD patterns, MIR and NIR spectra of distinct facies from the Itajaí Basin show that the content of smectite and R0 illite–smectite mixed layer minerals (I–S MLMs) increases towards shallower and proximal settings of the delta deposits, while

fossiliferous horizons display similarities with tuffs and tuffites (Supplementary Figs. 9–19, Dataset 1). The similarities of fossiliferous beds and volcanic sediments (i.e., the higher illite content) in the IR absorption bands are clearer in the Si-O-Si stretching region near 1030 $cm^{-1}$, in the OH stretching band near 3622 $cm^{-1}$ and in the 2v(OH) overtone in the NIR region near 7072 $cm^{-1}$. It is interesting to note also that the absorption bands related to the presence of Mg in octahedral sheets seems to be more intense in the fossiliferous levels and volcanic sediments, corroborating the data from the elemental analyses (main text).

The smectite enrichment in proximal facies likely reflects river-borne sediments, similar to those observed in modern cases (Meunier, 2005). Conversely, the random occurrence of kaolinite–smectite MLMs, as well as its disordered and iron-rich nature (Supplementary Fig. 9–12, 15–18), suggests a later formation stage by acidic alteration of original clay minerals and/or other minerals (e.g. feldspars, micas), as seen in thin sections (data not shown). Interestingly, the turbidite complex of the depositional sequence 2 (DS2) also showed an increase in smectite content, which likely reflects the reworking of the previous deltaic deposits. Chlorite–smectite MLMs are also present in some samples and its concentration increases in localities closer to intruding rhyolite bodies or to the basin border. This suggests that this Chl–S MLMs results from the later alteration of smectite-rich rocks near these zones.

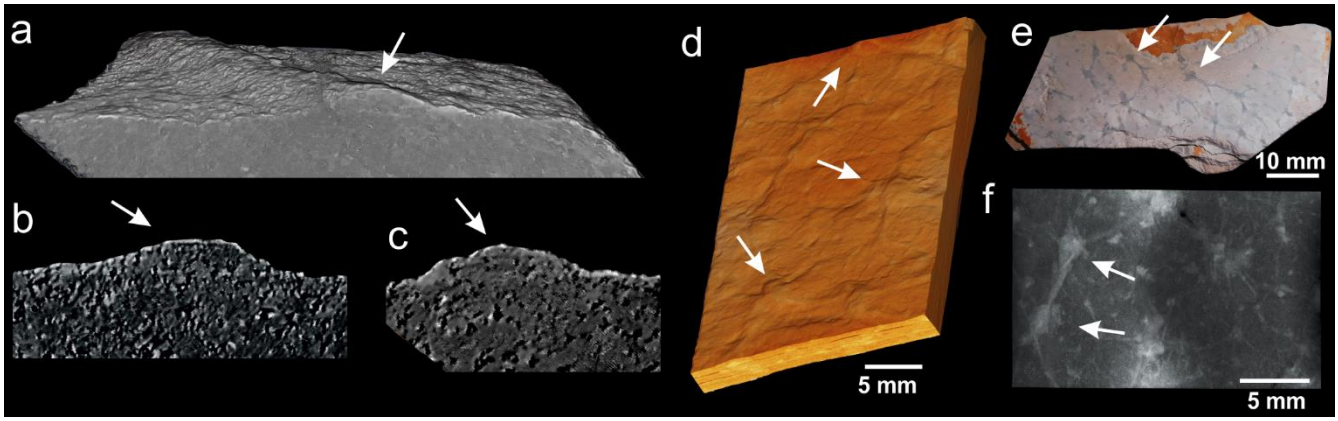
In sum, the results show a complex clay assemblage for the Itajaí Basin, related to sedimentological and diagenetic processes. Importantly, we corroborate the genetic association of the authigenic clays in the fossils and in the volcanic sediments, ruling out other hypotheses for clay enrichment in the fossiliferous surfaces and structures.

**Supplementary Text 3 - Raman spectroscopy results**

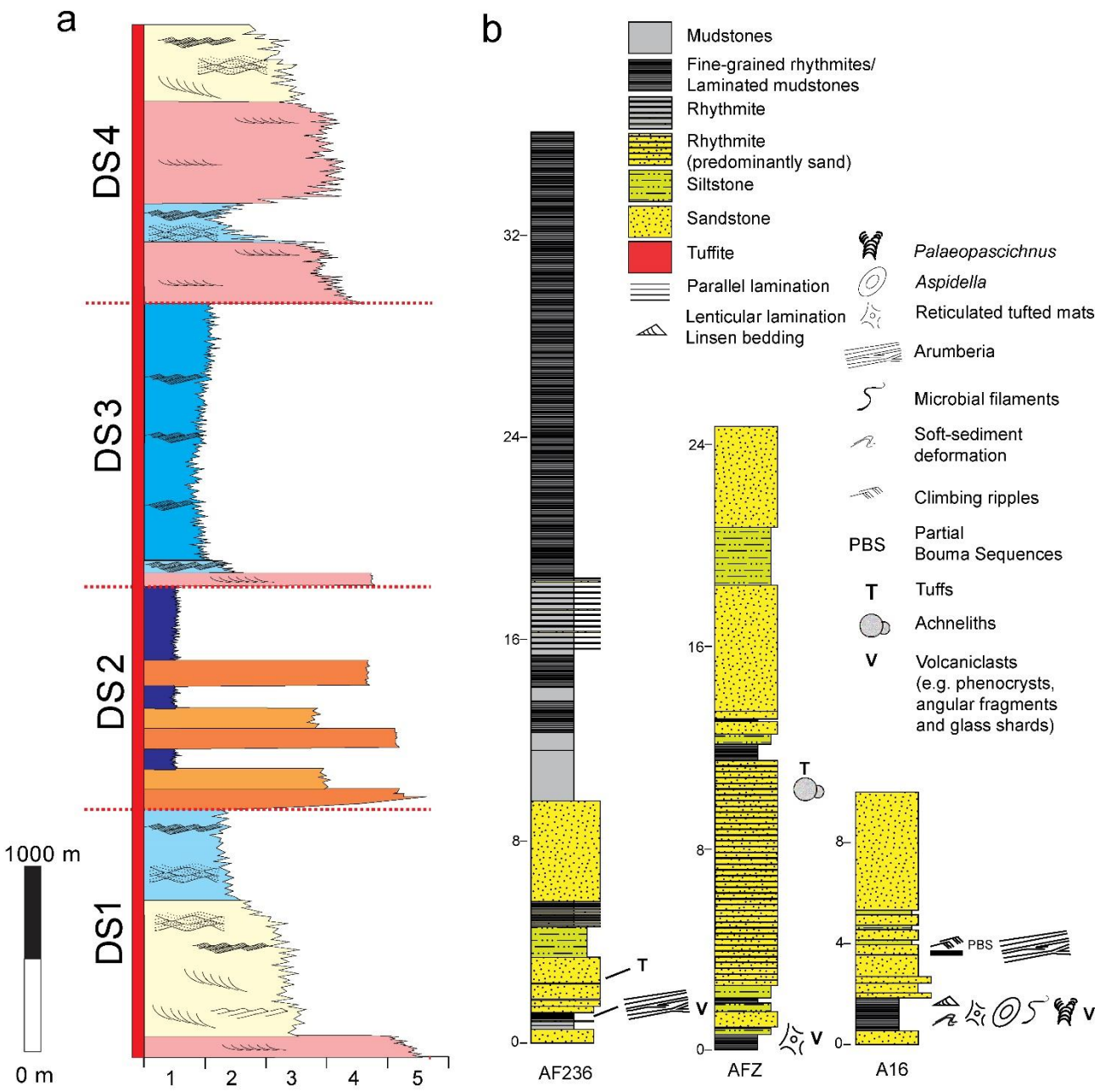
Statistical comparisons of the values obtained by the fitting of the Raman point analyses (Dataset S3) showed that bands of illite are more prevalent in FRCs than in the matrix/cement. Despite that the spectra from the matrix/cement also showed illite, the higher presence of quartz is evident by the common appearance of the weak quartz band near 355 $cm^{-1}$. The concentration of clay minerals in the fossils is further evidenced by the higher ratios of 700 $cm^{-1}$/464 $cm^{-1}$ peak area (Supplementary Fig. 21). Higher full width at half maximum (FWHM) values and lower positions of the peak near 464 $cm^{-1}$ also differentiate the fossils from the matrix (Supplementary Fig. 21). These features are related to the higher influence of the illite band near 464 $cm^{-1}$,

instead of the one representing quartz (Supplementary Fig. 21). When compared to detrital micas, the peak at 700 $cm^{-1}$ from both the FRCs and matrix clays show similar positions and higher FWHM variation, reflecting not only different mineralogy from the detrital micas, but also a less crystallized clay mineral of authigenic origin.

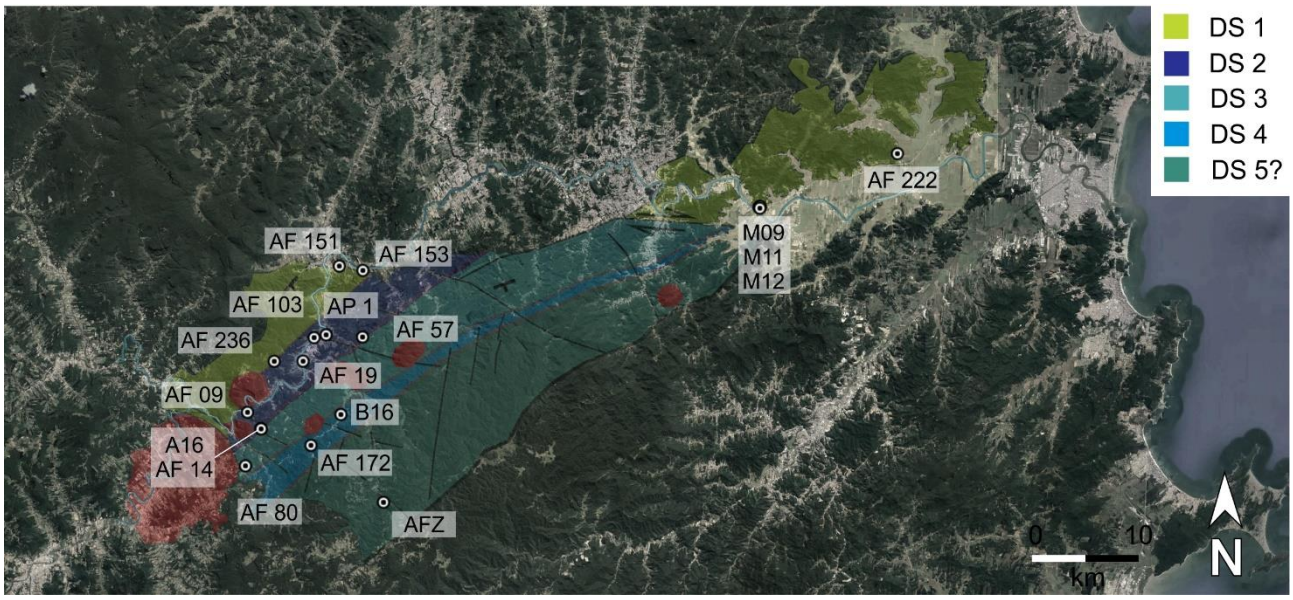
Raman point analyses in randomly chosen $TiO_2$ crystals showed a higher proportion of anatase (ca. 147 $cm^{-1}$, 399 $cm^{-1}$, 639 $cm^{-1}$) (compared to rutile) in the FRCs (87.9%; n = 66) than the host rock (66.1%; n = 65) (Dataset S4). Moreover, the point analyses in the clay minerals demonstrated the elevated presence of disseminated fine-grained anatase (Fig. 3e) in the fossils (98.8%, n = 81) compared to the points in the matrix/cement (39.8%, n = 93) (Dataset S3, 4).



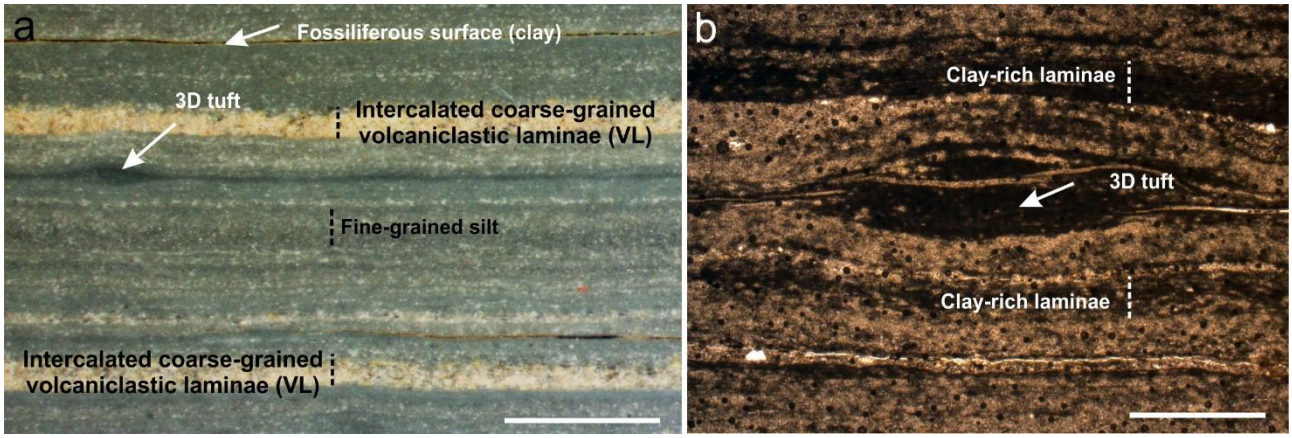

**Supplementary Figure 1**. **µCT of microbial filaments and 3D microbial tufts**. (**a)** 3D reconstruction of microbial filaments and sectional views. (**b-c)** The same clastic texture in the fossils as in the matrix. (**d)** 3D view of the surface of a sample containing preserved tufts that can be distinguished from the surrounding rock in polished (**e**) and microtomographic sections (**f**).



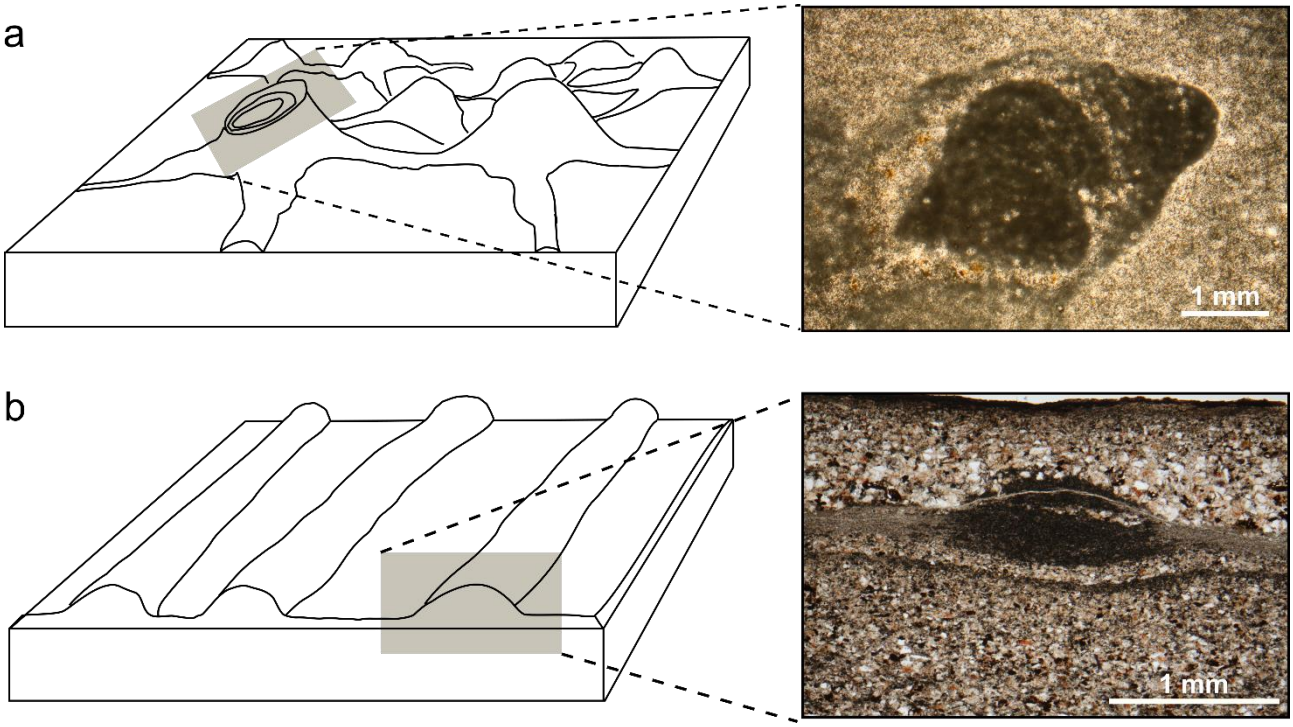

**Supplementary Figure 2**. **Stratigraphic framework of the Itajaí Basin**. **(a)** A generalized stratigraphic column of the basin, with the main depositional sequences: DS1; DS2; DS3; and DS4. Depositional Sequence 5 was omitted due to its uncertain stratigraphic relationship. **(b)** Stratigraphic logs of the main fossiliferous outcrops: AF236; AFZ; and A16.



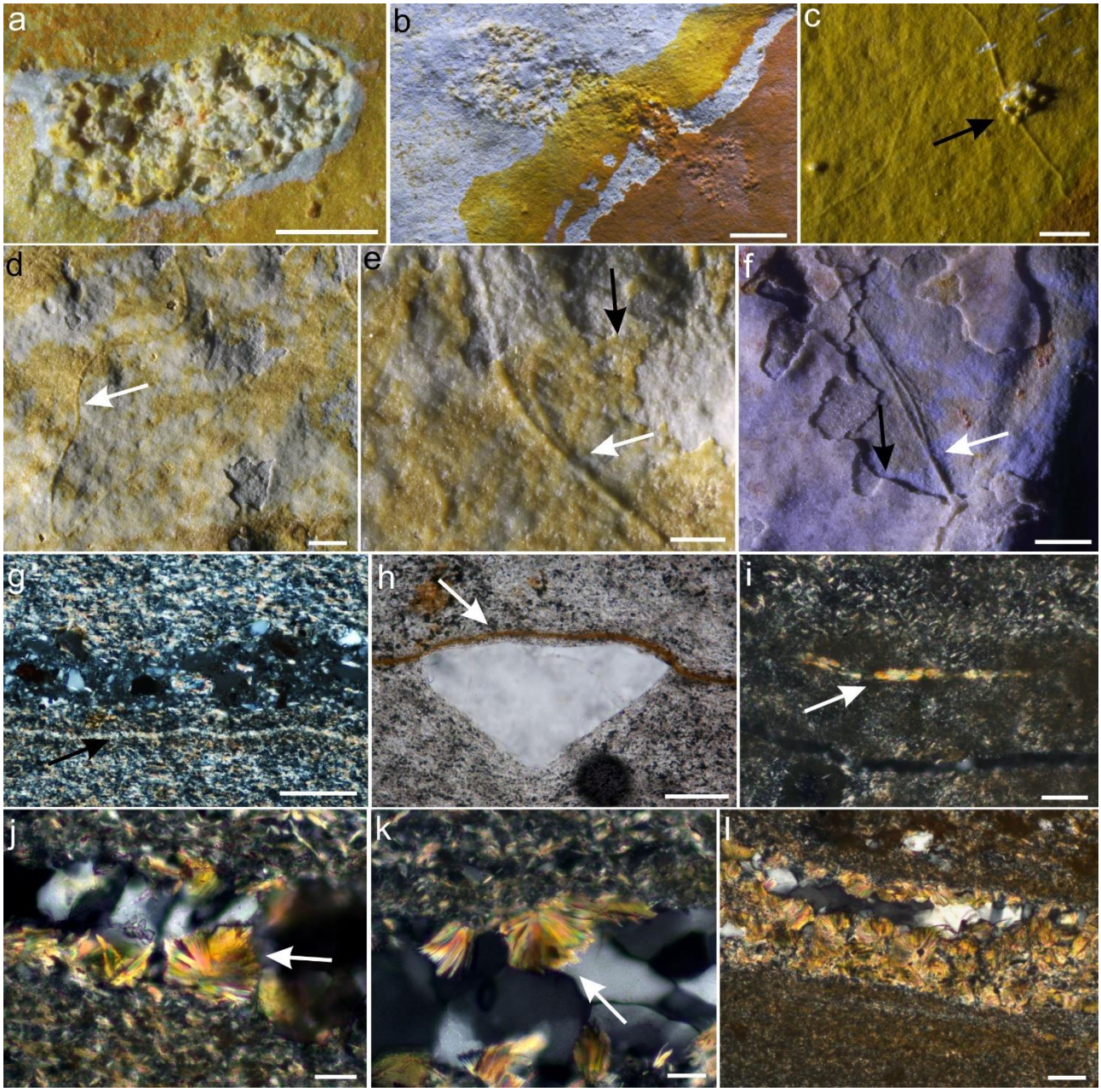

**Supplementary Figure 3**. **Geographic localization of the outcrops investigated in this study.** The depositional sequences occur from northwestern to southeastern as from base to top, being: DS1, DS2, DS3, DS4, and DS5.



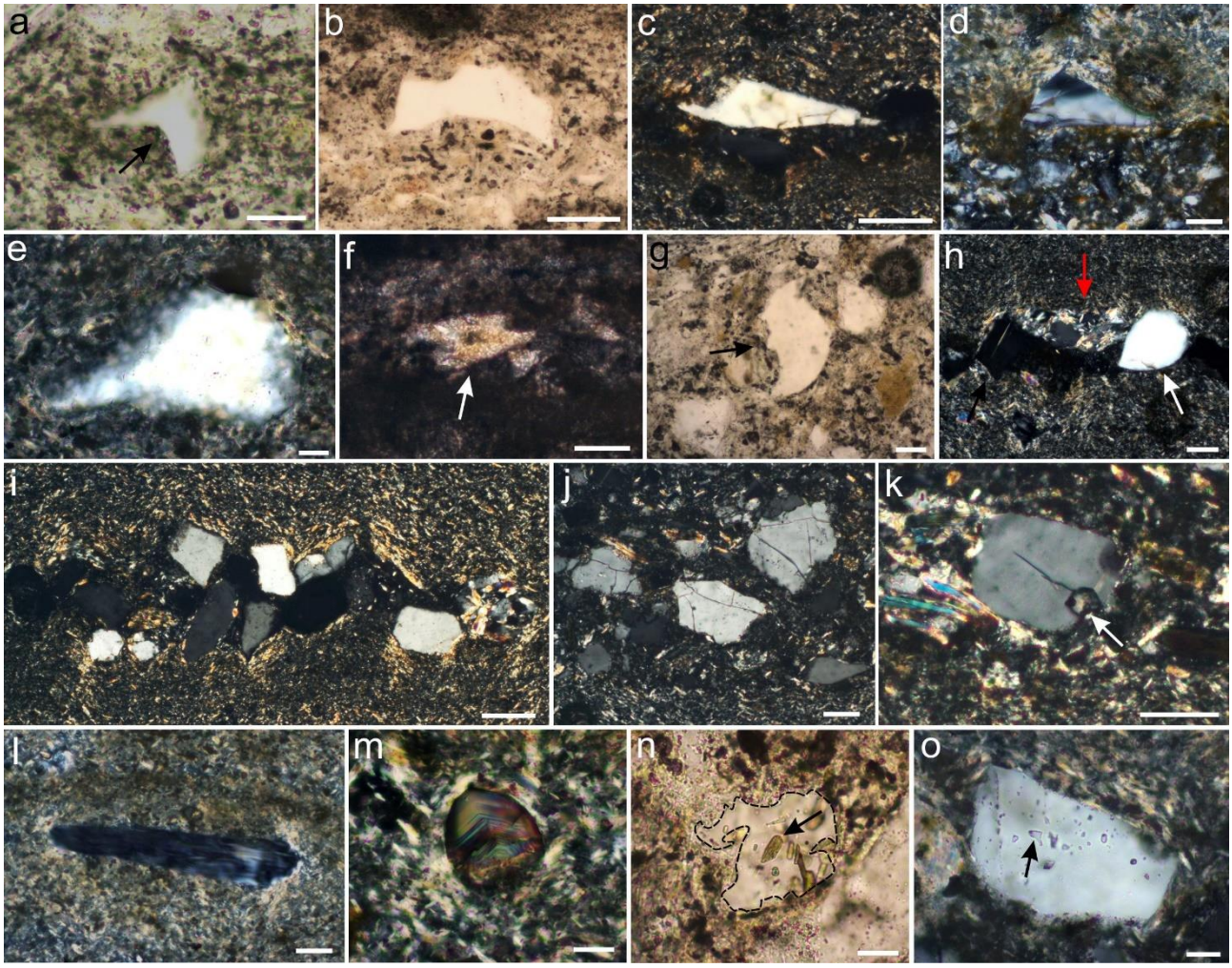

**Supplementary Figure 4**. **Sedimentary laminae. (a)** Polished cross-section of a hand sample showing the millimeter-scale laminations comprising clay, fine-grained silt and coarse-grained volcaniclastic silt (VL), and the clays preserving the the-dimensional microbial mats. **(b)** Thin section in plane-polarized light of a similar sample showing the opaque clay-rich laminae intercalated with very fine silt. Scale: 2 mm (a); 1 mm (b).



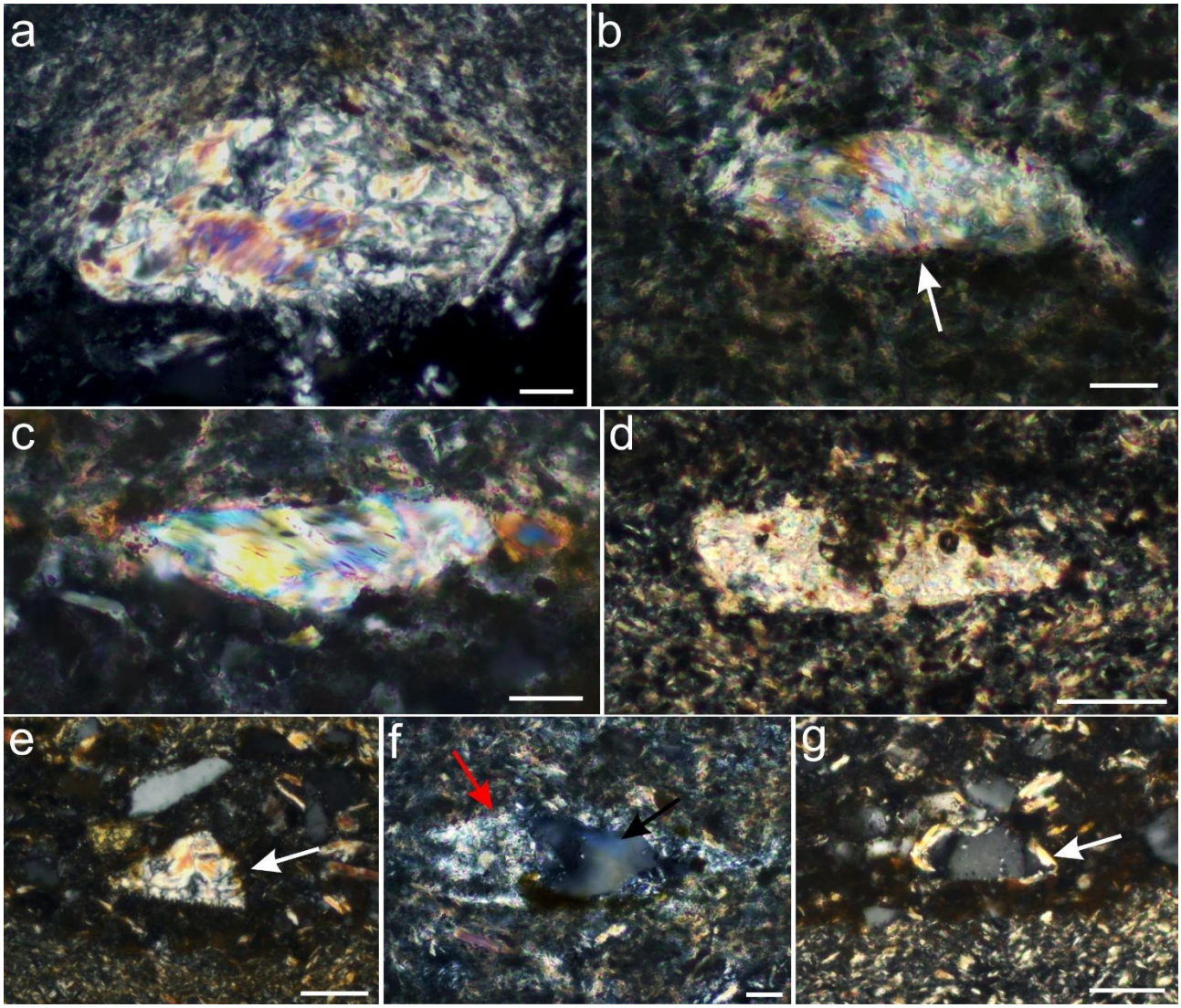

**Supplementary Figure 5. Three-dimensionally preserved microbial mats. (a)** Reticulated mats. **(b)** Arumberia-like mats. Insets showing the specific orientations of the thin sections figured to the right.



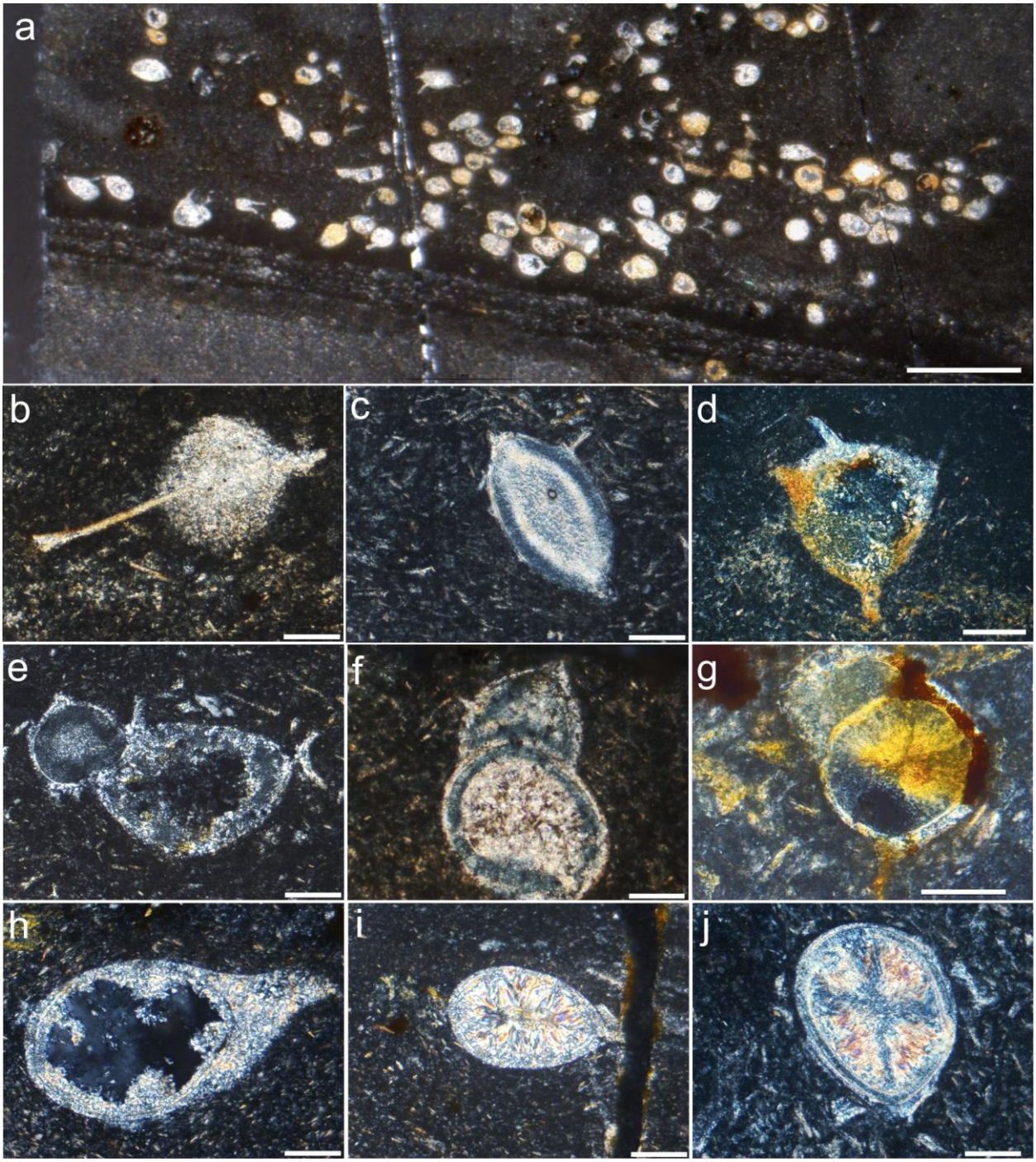

**Supplementary Figure 6. Ash layers and associated features. (a**, **b)** Slightly reworked accretionary pellets composed of euhedral pyroclasts. **(c)** Ash cluster associate with fossils. **(d-f)** Altered ash layers covering filamentous microfossils. **(g)** Fine-grained ash layer in thin section, similar to those in the hand samples (d, e). **(h)** Altered fine-grained ash layer covering large euhedral clast. **(i)** Initial development of fibrous sericite following bedding planes. **(j–l)** Early-formed fractures filled with fibrous radial sericite and quartz. Scales: 1 mm (a, c, d, f); 2 mm (b); 0.5 mm (e); 100 µm (g); 50 µm (h, i, l); 20 µm (j, k).



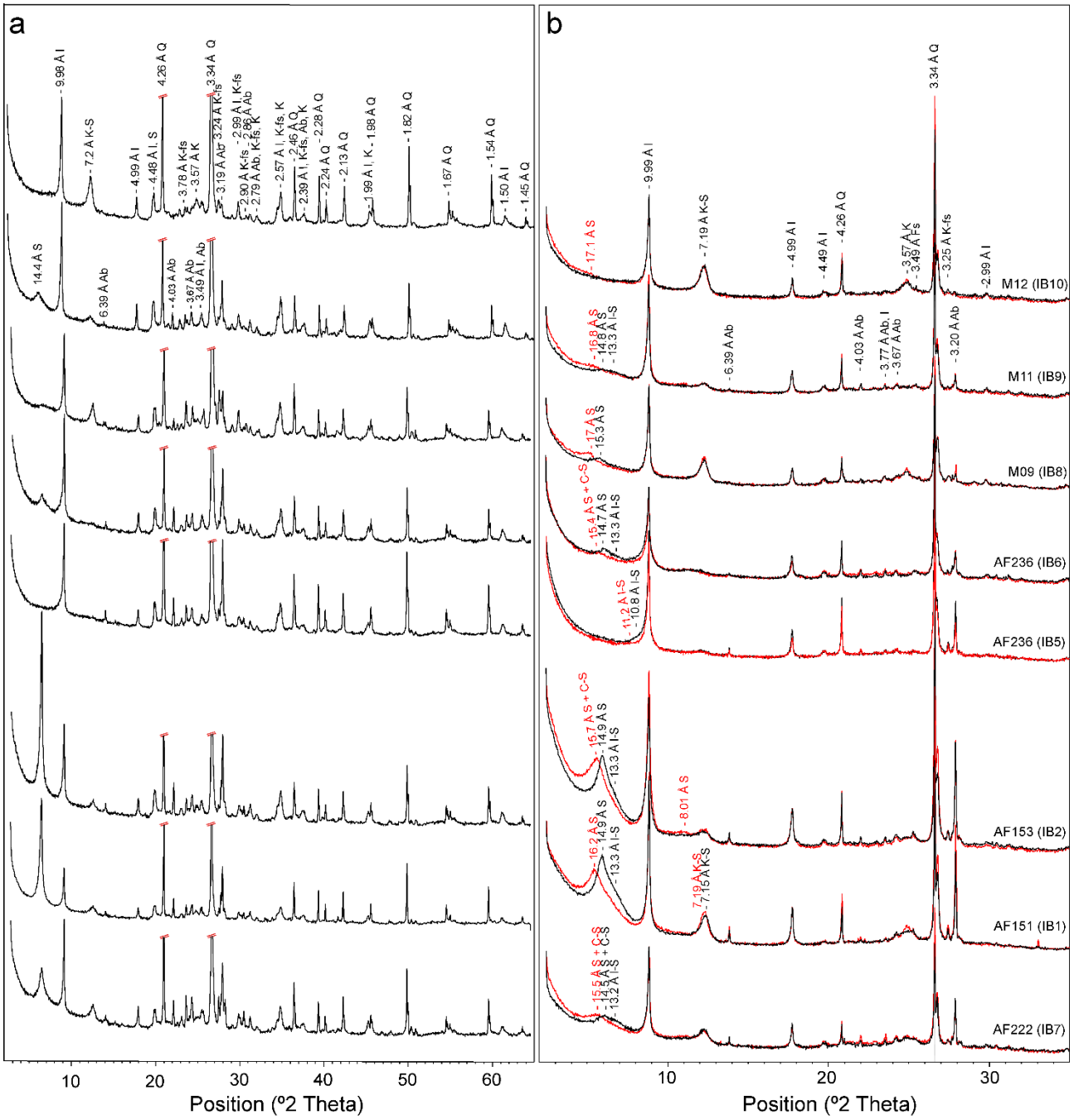

**Supplementary Figure 7. Glass shards and other pyroclasts. (a–f)** Vitric clasts and possible glass shards found associated with the fossiliferous surfaces. **(g–h)** Smooth shards with fluidal shapes. **(i–j)** Thin section of accretionary pellets, showing large euhedral phenocrysts, some of which are broken. **(k)** Phenocryst with vesiculated surface. **(l)** Phenocryst of perthite. **(m)** A zircon clast. **(n)** Apparently dissolved vitric clast with melted inclusions. **(o)** A vitric clast with fluid inclusions. Scales: 20 µm (a, e, m–o); 50 µm (b, d, f–h, j–l); 100 µm (c, i).



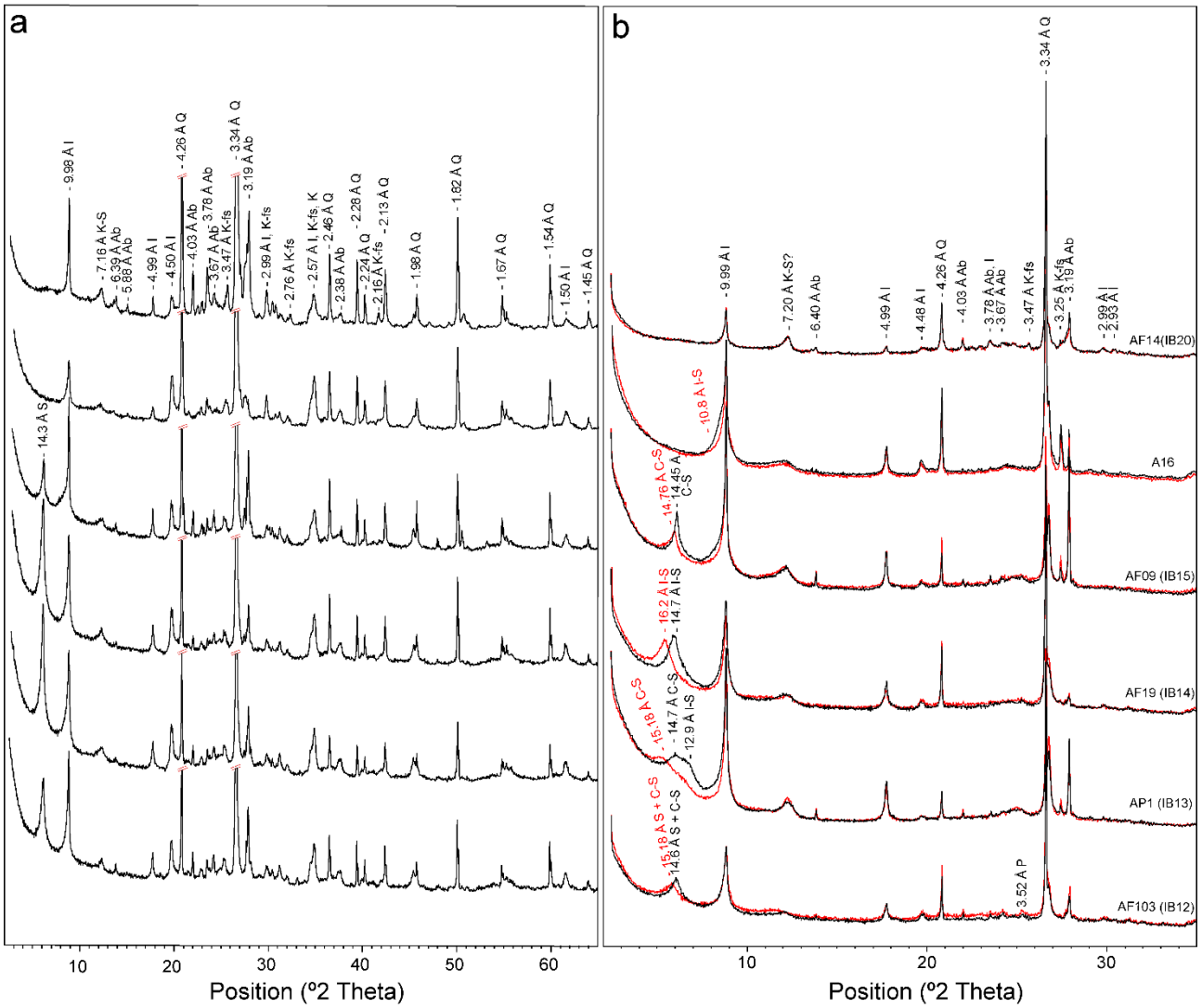

**Supplementary Figure 8. Devitrified glass shards, glassy fragments and clay rims**. (**a–d)** Devitrified glassy clasts with angular or rounded morphologies. **(e)** Devitrified euhedral pyroclast. **(f)** Glass shard devitrified to clay minerals on the exterior and to quartz in the central region. **(g)** euhedral phenocryst with clay rims. Scales: 20 µm (a–c, f); 50 µm (d, e, g).



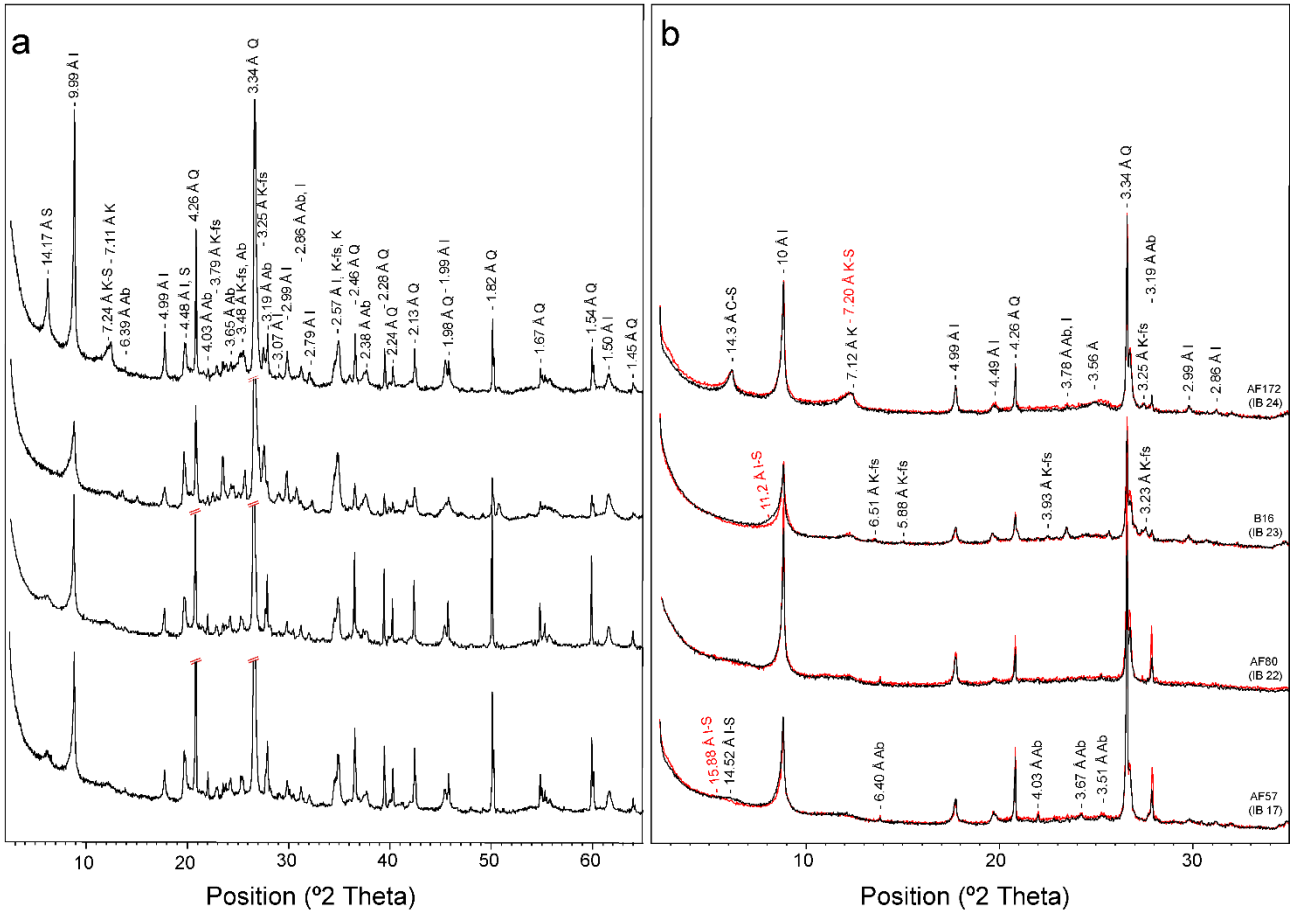

**Supplementary Figure 9. Glass spheres in cherty tuffites of the AFZ outcrop**. (**a)** Large concentration of slightly transported glass spheres. **(b–d)** Spheroidal to ellipsoidal shapes with spiny projections. **(e–g)** Conjoined spheres suggesting subaerial origin by impact. **(h)** A glass sphere with morphology analogous to vase-shaped microfossils. **(i–j)** Ellipsoidal glass spheres with clear devitrification features. Scales: 1 mm (a); 100 µm (b–f, h–j); 50 µm (g).



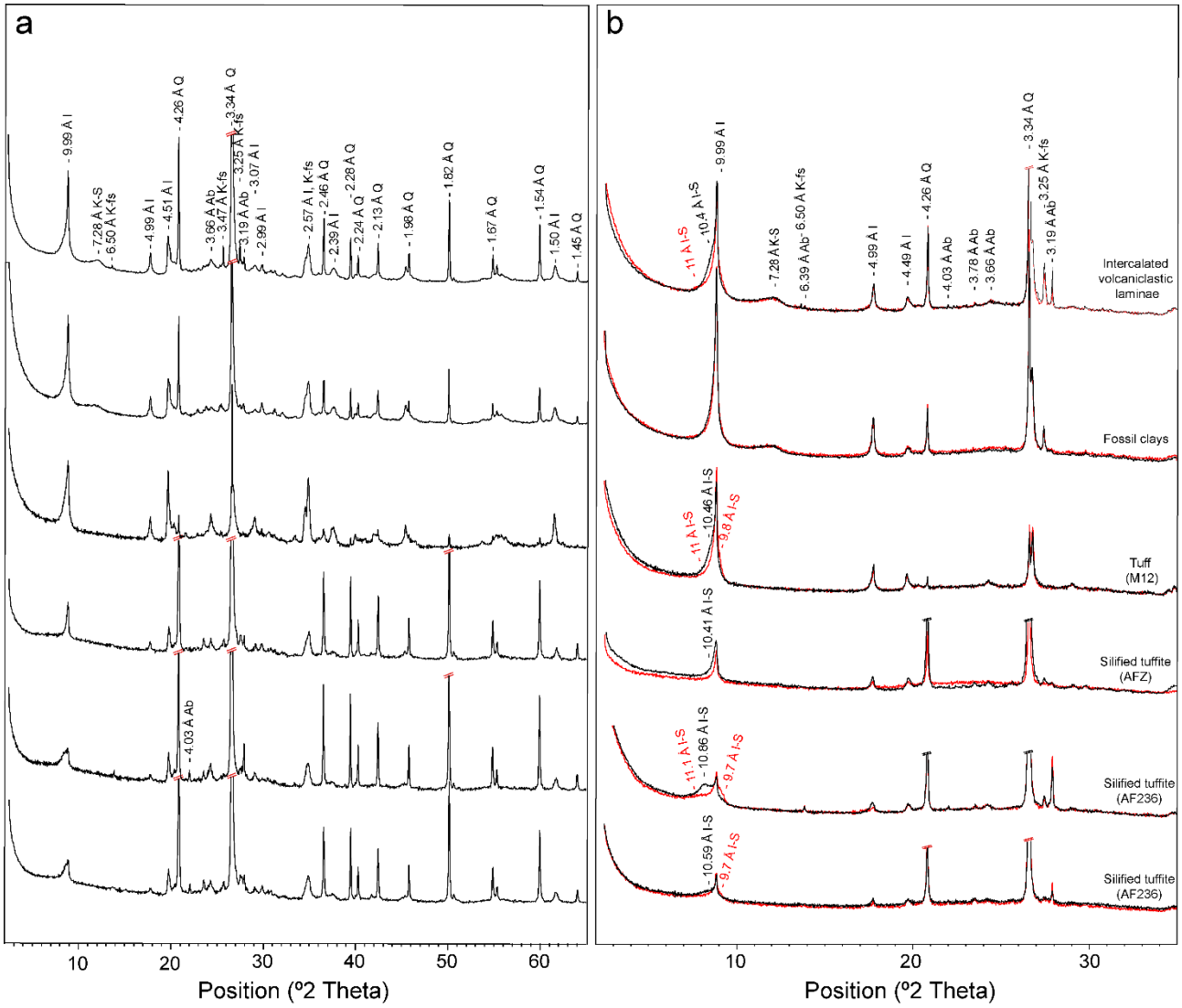

**Supplementary Figure 10. XRD patterns of representative samples from the depositional sequence 1.** Graphs are organized by their relative stratigraphic position in the DS1. **(a)** Bulk powder and **(b)** clay size-fractions (<2 µm). Note the higher content of smectite and/or smectite-rich I–S MLMs in the lower sections (more proximal depositional settings). I – Illite; S – Smectite; Q – Quartz; K-fs – K-feldspar; Ab – Albite; K – Kaolinite; I-S – Illite-Smectite mixed layer; C-S – Chlorite-Smectite mixed layer; K-S – Kaolinite-Smectite mixed layer.



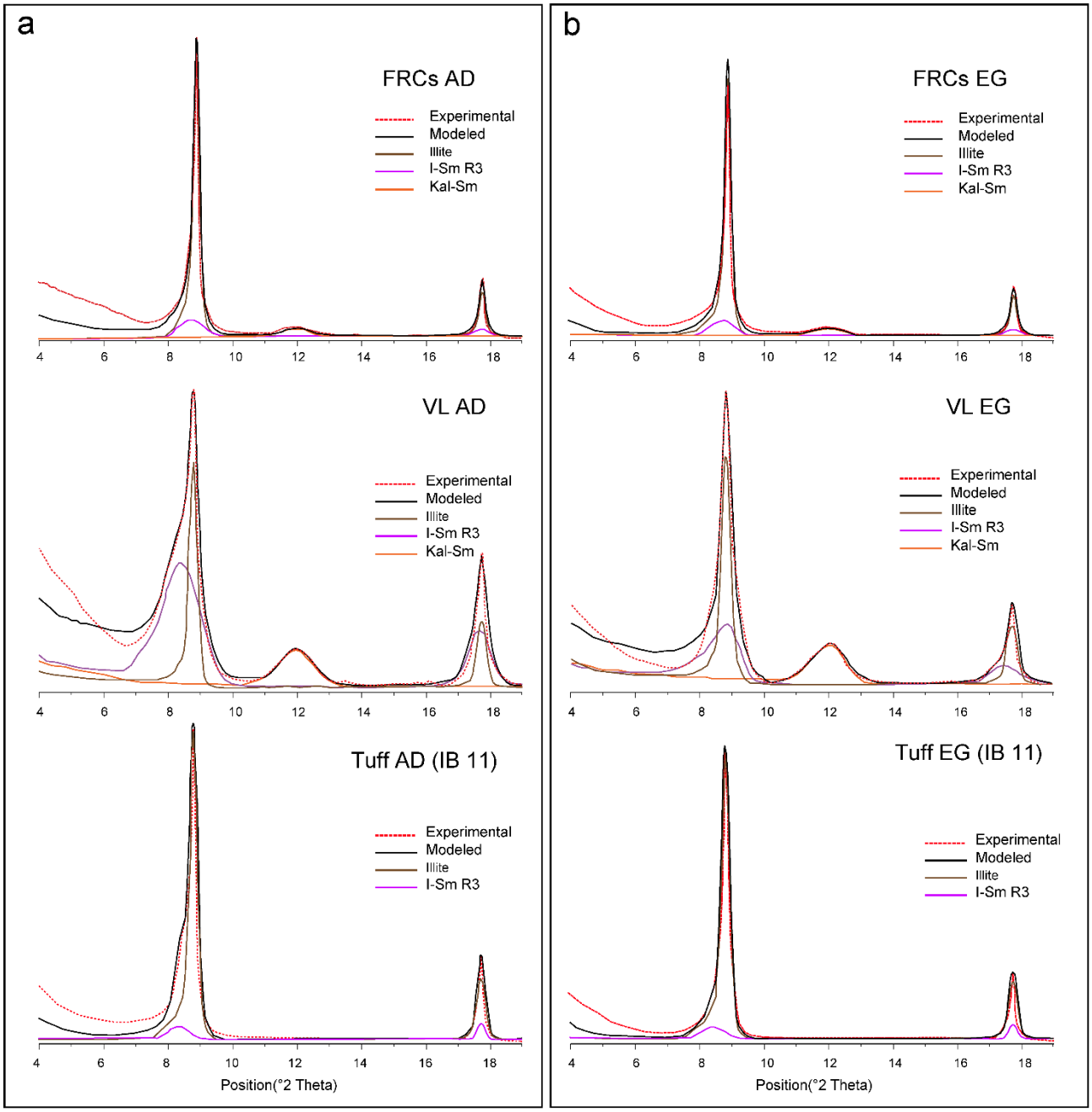

**Supplementary Figure 11. XRD patterns of representative samples from the depositional sequence 2.** Graphs are organized by their relative stratigraphic position in the DS2. (**a)** bulk powder and **(b)** clay fractions (< 2 µm). Note the higher smectitic content in the turbiditic complex of the DS2 (IB 12–15). Sample A16, which represents the fossiliferous outcrop, presenting R3 I–S MLMs. I – Illite; S – Smectite; Q – Quartz; K-fs – K-feldspar; Ab – Albite; K – Kaolinite; I-S – Illite-Smectite mixed layer; C-S – Chlorite-Smectite mixed layer; K-S – Kaolinite-Smectite mixed layer.



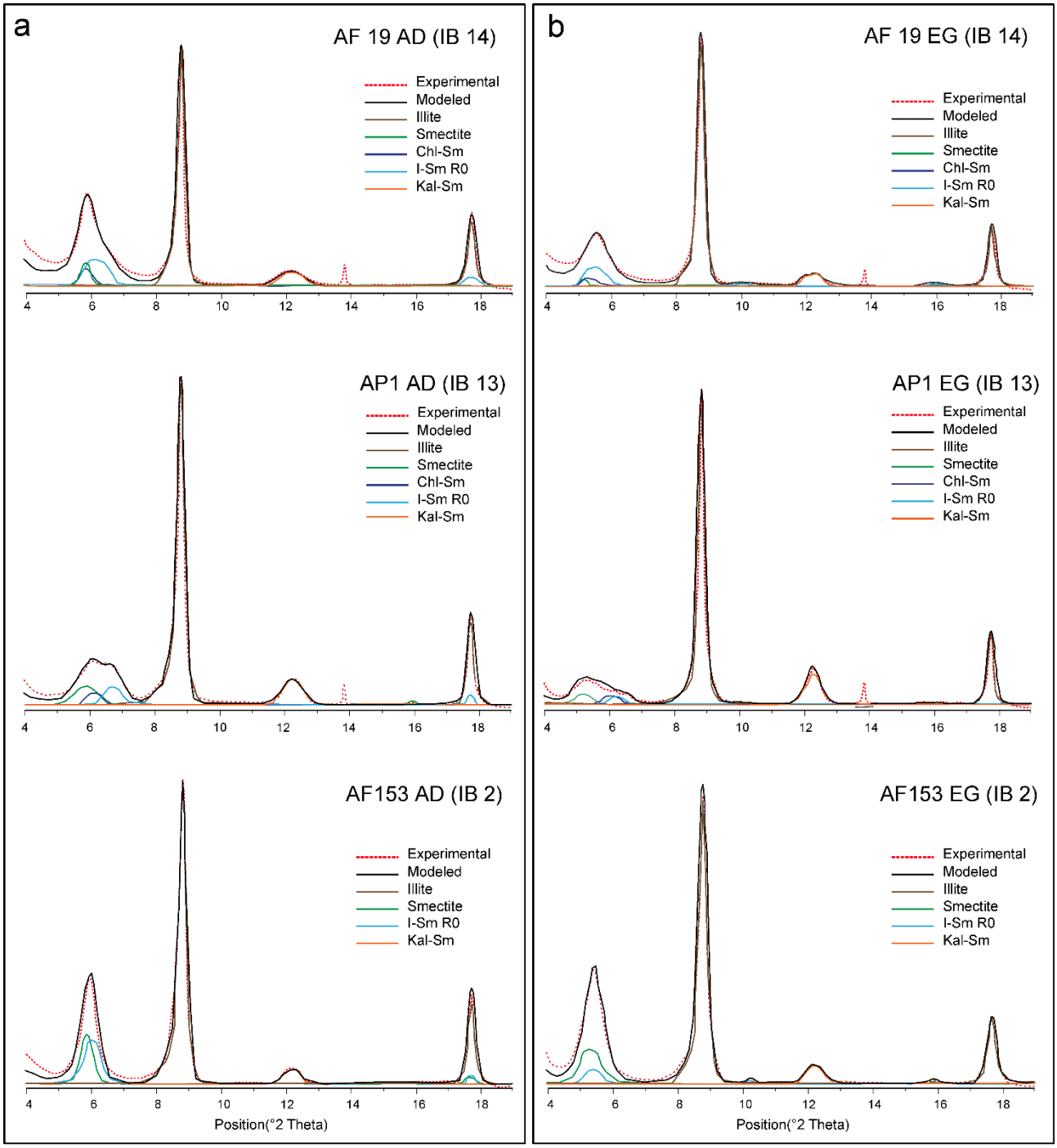

**Supplementary Figure 12. XRD patterns of representative samples from the depositional sequence 3 (distal settings of AF57; B16) and 4 (proximal settings of AF172). (a)** bulk powder and (**b)** clay fractions (< 2 μm). Sample B16 represents a fossiliferous outcrop. Note the presence of illite-rich I–S MLMs in B16. I – Illite; S – Smectite; Q – Quartz; K-fs – K-feldspar; Ab – Albite; K – Kaolinite; I-S – Illite-Smectite mixed layer; C-S – Chlorite-Smectite mixed layer; K-S – Kaolinite-Smectite mixed layer.



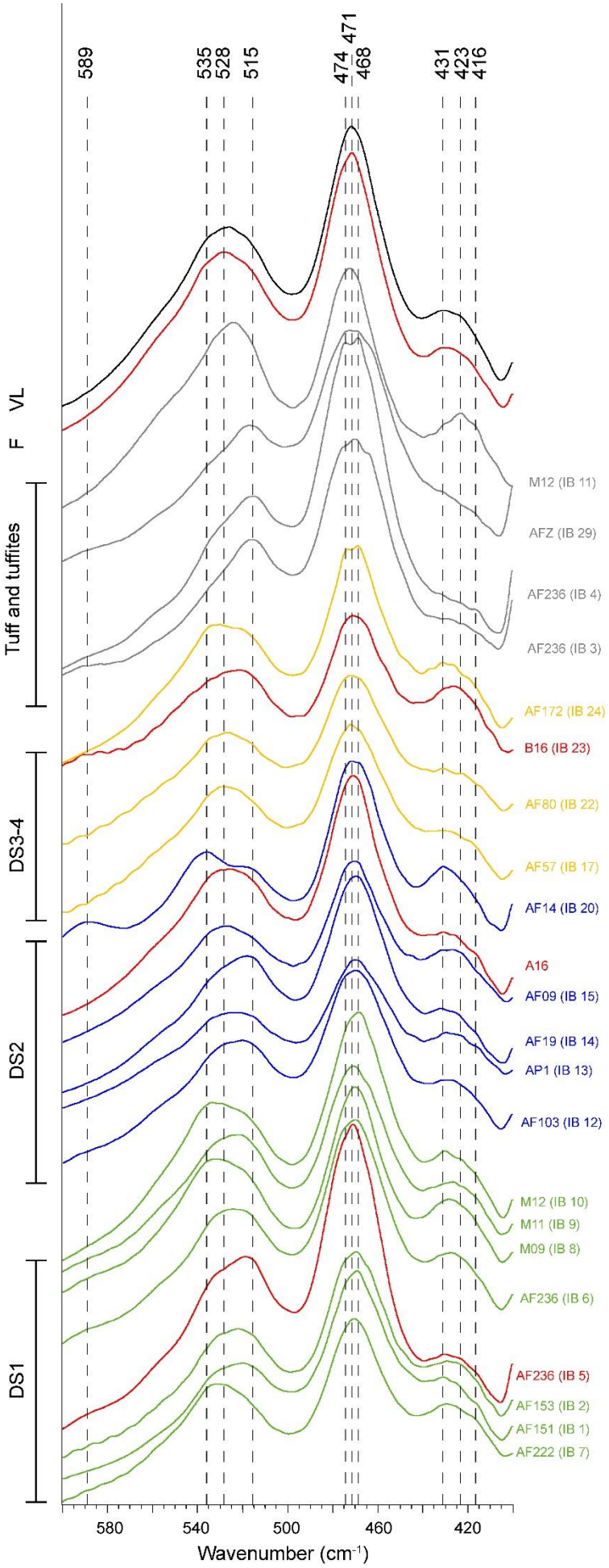

**Supplementary Figure 13. XRD patterns from the tuff (M12), tuffites (AF236, AFZ), fossil clays, and intercalated volcaniclastic coarse-grained laminae (VL). (a)** bulk powder and **(b)** clay fractions (< 2 μm). Note illite-rich I–S MLMs in all samples except those extracted from the fossil lamina. I – Illite; S – Smectite; Q – Quartz; K-fs – K-feldspar; Ab – Albite; K – Kaolinite; I-S – Illite-Smectite mixed layer; C-S – Chlorite-Smectite mixed layer; K-S – Kaolinite-Smectite mixed layer.



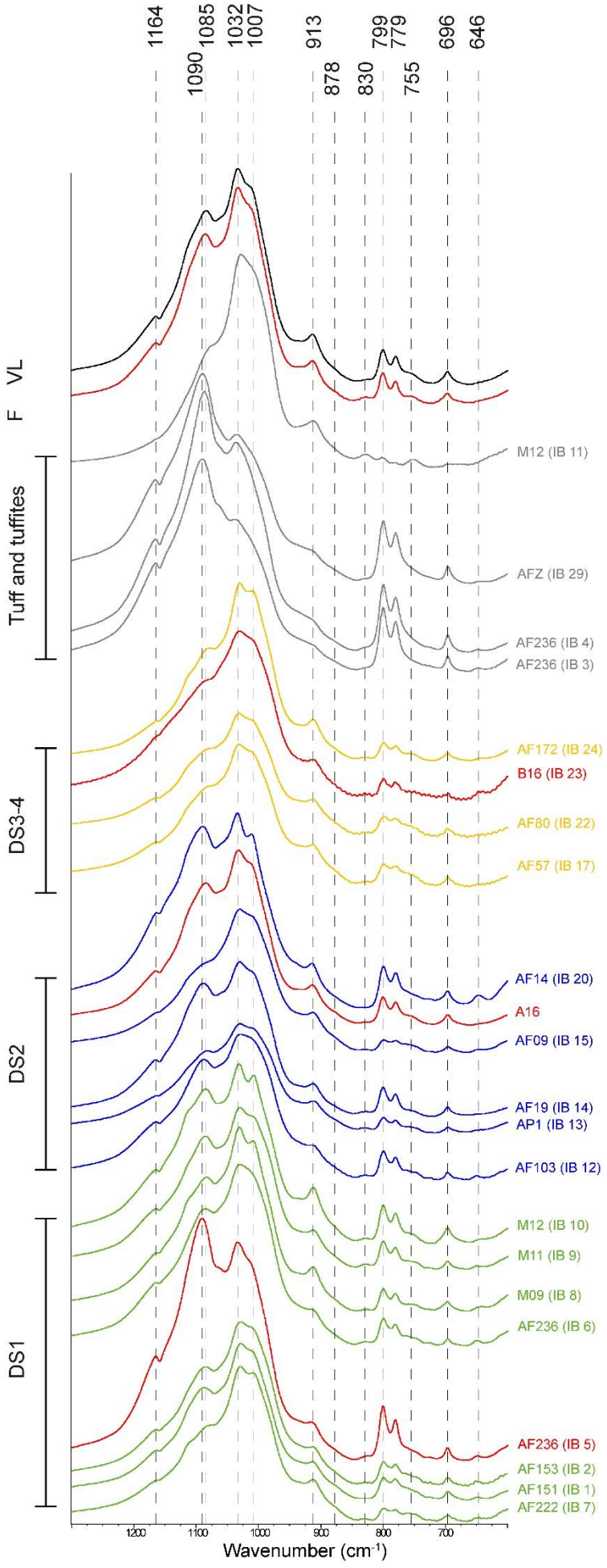

**Supplementary Figure 14. Experimental (dashed lines) and modeled (continuous lines) XRD profiles by Newmod of fossil clays (FRCs), volcaniclastic laminae (VL) and tuff clays, showing the R3 I–S MLMs ordering. (a)** After air-dried preparation (AD) and **(b)** after ethylene-glycol saturation (EG).



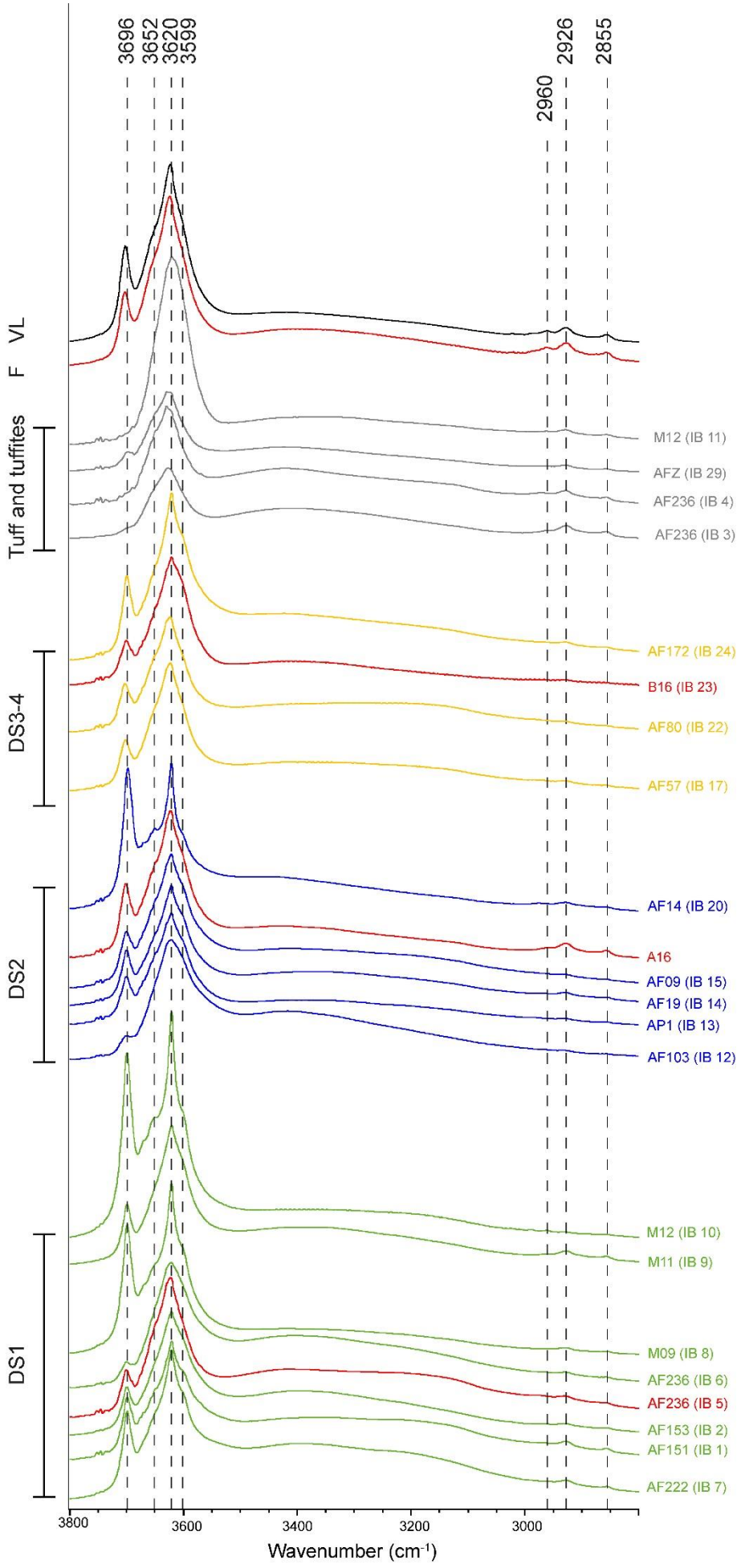

**Supplementary Figure 15. Experimental (dashed lines) and modeled (continuous lines) XRD profiles by Newmod of representative samples from smectite-rich facies, showing the R0 I–S MLMs ordering. (a)** After air-dried preparation (AD) and **(b) after** ethylene-glycol saturation (EG).


589
535
528
515
474
471
468
431
423
416
F VL
Tuff and tuffites
DS3-4
DS2
DS1
M12 (IB 11)
AFZ (IB 29)
AF236 (IB 4)
AF236 (IB 3)
AF172 (IB 24)
B16 (IB 23)
AF80 (IB 22)
AF57 (IB 17)
AF14 (IB 20)
A16
AF09 (IB 15)
AF19 (IB 14)
AP1 (IB 13)
AF103 (IB 12)
M12 (IB 10)
M11 (IB 9)
M09 (IB 8)
AF236 (IB 6)
AF236 (IB 5)
AF153 (IB 2)
AF151 (IB 1)
AF222 (IB 7)
580
540
500
460
420
Wavenumber (cm-1)

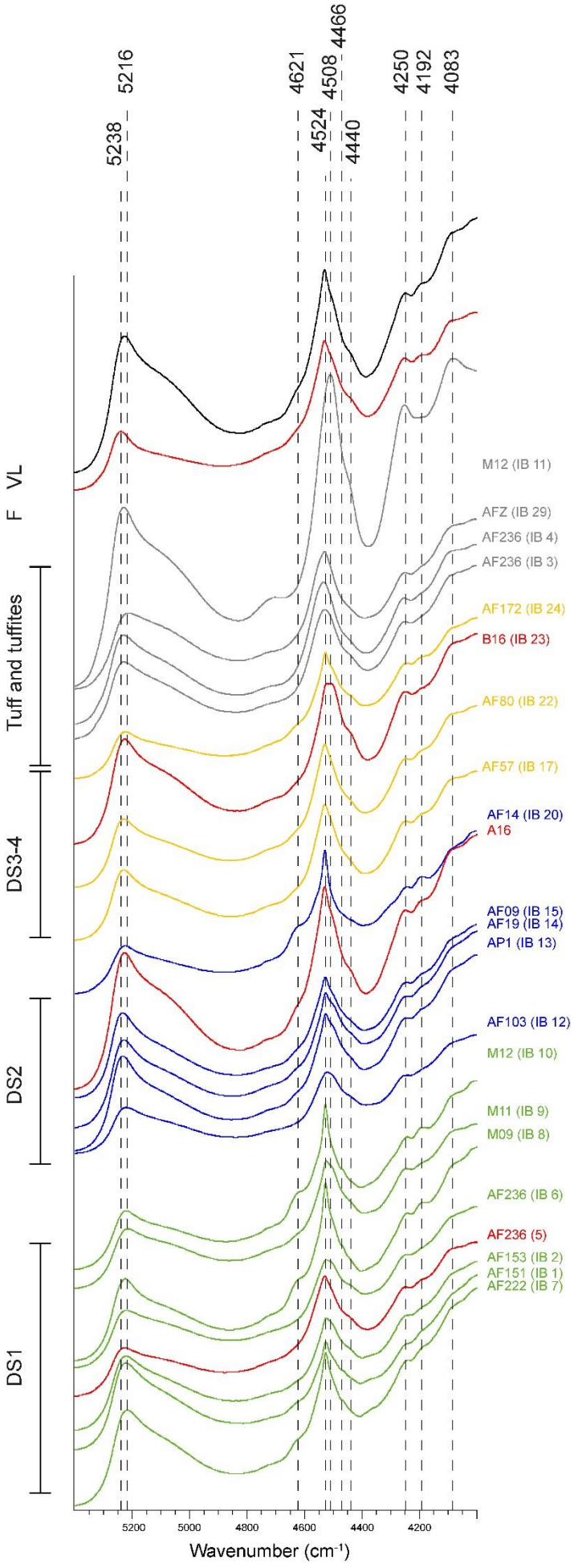
**Supplementary Figure 16. Infrared spectra of the clay fractions in the 600-400 $cm^{-1}$ region**. The bands between 420 and 431 $cm^{-1}$ are a mixture of the bands of illite (ca. 426 $cm^{-1}$) and kaolinite (ca. 431 $cm^{-1}$). The band near 470 $cm^{-1}$ can be assigned to the Si–O–Si bending, and shifts to higher frequencies (471–472 $cm^{-1}$) can be also related to illite or kaolinite bands, while lower frequencies (469 $cm^{-1}$) are more similar to some reported values of smectite (Russell and Fraser, 1994). The bands between 515 $cm^{-1}$ and 535 $cm^{-1}$ can be assigned to the Si–O–$Al^{VI}$ bending vibration (Farmer, 1974). Higher frequencies (~532 $cm^{-1}$) could be related to kaolinite bands, while intermediate (~529 $cm^{-1}$) and lower frequencies (~520 $cm^{-1}$) are closer to illite and smectite values, respectively. Bands around ~589 $cm^{-1}$ are attributed to albite(Russell and Fraser, 1994). For details see Dataset S1.


1164
1090
1085
1032
1007
913
878
830
799
779
755
696
646
F VL
Tuff and tuffites
DS3-4
DS2
DS1
M12 (IB 11)
AFZ (IB 29)
AF236 (IB 4)
AF236 (IB 3)
AF172 (IB 24)
B16 (IB 23)
AF80 (IB 22)
AF57 (IB 17)
AF14 (IB 20)
A16
AF09 (IB 15)
AF19 (IB 14)
AP1 (IB 13)
AF103 (IB 12)
M12 (IB 10)
M11 (IB 9)
M09 (IB 8)
AF236 (IB 6)
AF236 (IB 5)
AF153 (IB 2)
AF151 (IB 1)
AF222 (IB 7)
1200
1100
1000
900
800
700
Wavenumber (cm-1)

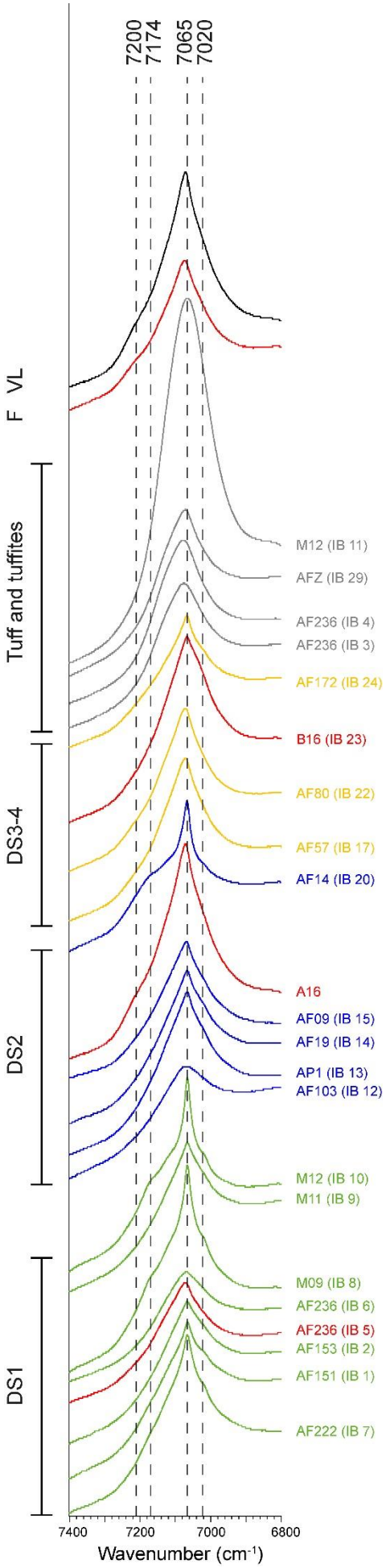
**Supplementary Figure 17**. **Infrared spectra of the clay fractions in the 1300–600 $cm^{-1}$ region.** The broadening of the band near 1028 $cm^{-1}$ can be attributed to the Si–O–Si stretching vibrations in samples with higher smectite content. In samples with a higher illite composition, the Si–O–Si stretching vibration appear towards higher frequencies (1032 $cm^{-1}$), and the two strong bands near 1031 $cm^{-1}$ and 1008 $cm^{-1}$ can be attributed to the kaolinite Si–O–Si stretching vibrations. A weak band near 830 $cm^{-1}$ can be assigned to the $Al^{IV}$–O out of plane vibration or AlMgOH bending vibrations of illite (Farmer, 1974; Zviagina et al., 2015), and the band near 913 $cm^{-1}$ to the AlOHAl bending of illite, smectite or kaolinite. A weak inflexion near 878 $cm^{-1}$ can be related to the δ($AlFe^{3+}OH$) vibrations in kaolinite (Mendelovici et al., 1979; Petit and Decarreau, 1990). The typical absorption bands of quartz appear at 779 $cm^{-1}$, 799 $cm^{-1}$, and near 1085 $cm^{-1}$ and 1163 $cm^{-1}$. DS1 = Depositional Sequence 1; DS2 = Depositional Sequence 2; DS3-4 = Depositional Sequence 3 and 4; F = Fossil clays; VL = intercalated coarse-grained volcaniclastic laminae. For details see Dataset S1.


3696
3652
3620
3599
2960
2926
2855
F VL
Tuff and tuffites
DS3-4
DS2
DS1
M12 (IB 11)
AFZ (IB 29)
AF236 (IB 4)
AF236 (IB 3)
AF172 (IB 24)
B16 (IB 23)
AF80 (IB 22)
AF57 (IB 17)
AF14 (IB 20)
A16
AF09 (IB 15)
AF19 (IB 14)
AP1 (IB 13)
AF103 (IB 12)
M12 (IB 10)
M11 (IB 9)
M09 (IB 8)
AF236 (IB 6)
AF236 (IB 5)
AF153 (IB 2)
AF151 (IB 1)
AF222 (IB 7)
3800
3600
3400
3200
3000
Wavenumber (cm-1)

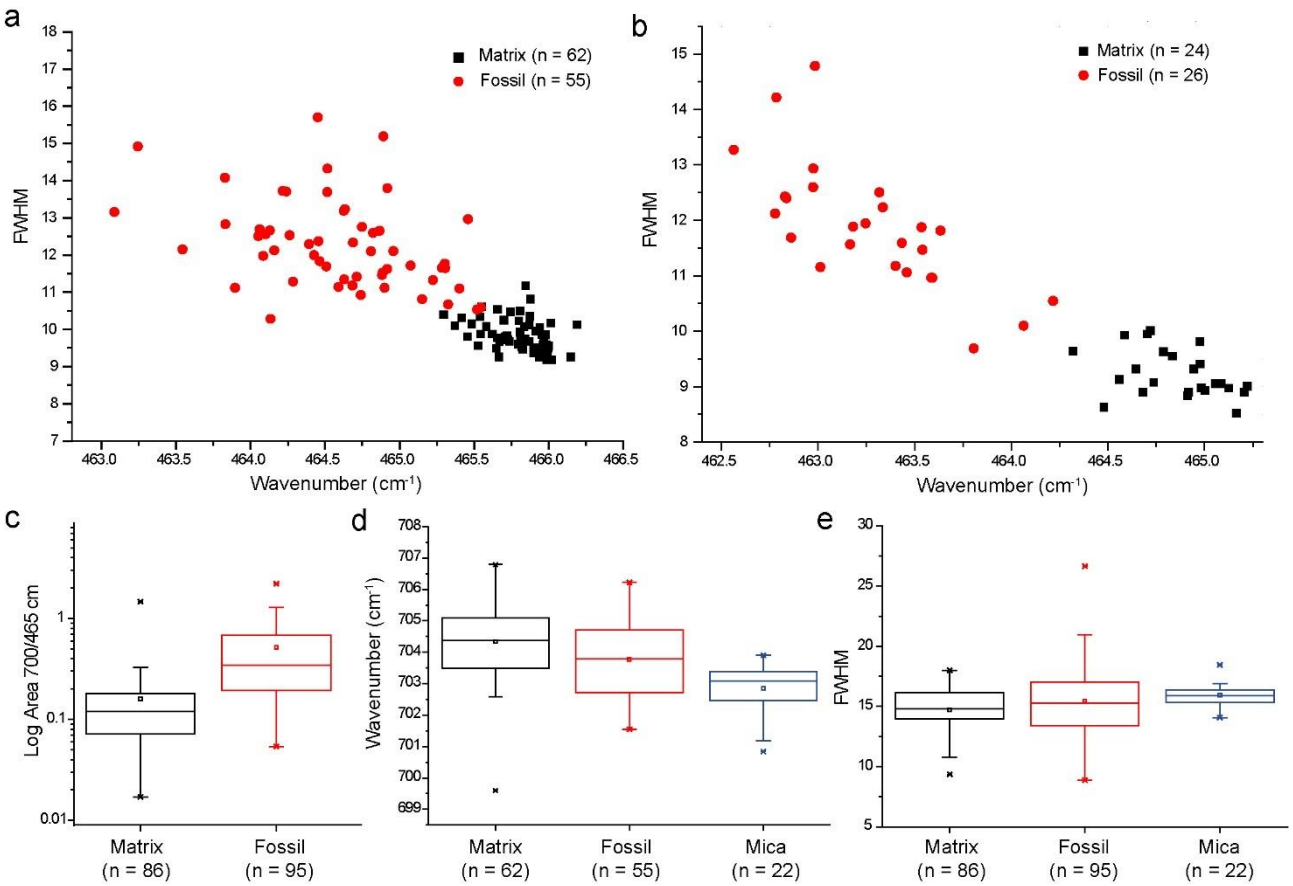
**Supplementary Figure 18**. **Infrared spectra of the clay fractions in the OH stretching region.** Absorption bands at 3696, 3620, ca. 3669 and ca. 3650 $cm^{-1}$ are typical of disordered kaolinite, and shoulders near 3600 $cm^{-1}$ can be attributed to $Fe^{3+}$ in their octahedral sheets (vAlFeOH). The broadening of the band near 3620 $cm^{-1}$ can be related to the presence of the OH-stretching of montmorillonite in the samples higher in smectite content, as seen by XRD patterns. The broadening at the same region also can be related to illite in the illite-rich samples. The broad band near 3420 $cm^{-1}$ in the smectite-rich samples can be related to the OH stretching of absorbed $H_2O$, which were not released upon heating. A weak shoulder near 3568 $cm^{-1}$ in few samples shows that nontronite can also be present in small quantities. Absorption bands between 3000–2800 $cm^{-1}$ reveal the presence of aliphatic hydrocarbons, relatively more intense in the fossiliferous substrates and volcanic rocks, but small peaks are present throughout almost all examined samples. These bands can be assigned to symmetric $CH_3$ stretching (near 2960 $cm^{-1}$), asymmetrical $CH_2$ stretching (near 2926 $cm^{-1}$) and symmetrical $CH_2$ stretching (near 2855 $cm^{-1}$). For details see Dataset S1.


5238
5216
4621
4524
4508
4466
4440
4250
4192
4083
F VL
Tuff and tuffites
DS3-4
DS2
DS1
M12 (IB 11)
AFZ (IB 29)
AF236 (IB 4)
AF236 (IB 3)
AF172 (IB 24)
B16 (IB 23)
AF80 (IB 22)
AF57 (IB 17)
AF14 (IB 20)
A16
AF09 (IB 15)
AF19 (IB 14)
AP1 (IB 13)
AF103 (IB 12)
M12 (IB 10)
M11 (IB 9)
M09 (IB 8)
AF236 (IB 6)
AF236 (5)
AF153 (IB 2)
AF151 (IB 1)
AF222 (IB 7)
5200
5000
4800
4600
4400
4200
Wavenumber (cm-1)

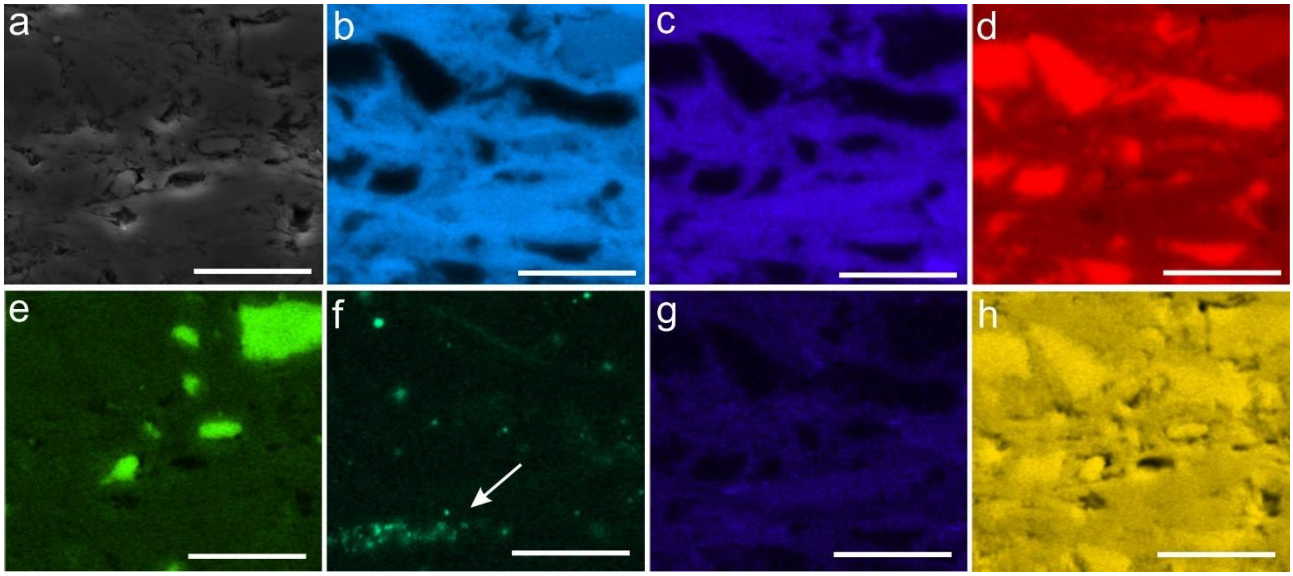
**Supplementary Figure 19**. **Near-Infrared spectra of the clay fractions in the 5300–4100 $cm^{-1}$ region.** The narrow band near 4527 $cm^{-1}$ can be attributed to kaolinite, as well as the weaker band near 4621 $cm^{-1}$. The broadening of the region near 4524 $cm^{-1}$ is observed in the smectite-rich samples, and can represent the combination bands of montmorillonite. The shoulder near 4466 $cm^{-1}$ can be correlated with the absorption band of $AlFe^{3+}OH$ and the shoulder near 4440 $cm^{-1}$ to (v+δ) AlMgOH (Madejová et al., 2017). Interestingly, the last shoulder is more pronounced in the fossiliferous samples and in the tuff, corroborating the previous presence of montmorillonite, which was later illitized. The shoulder near 4500 $cm^{-1}$ could be related to the structural OH in illite. The broad band near 5220 $cm^{-1}$ is assigned to the combination modes of the vibrations of water molecules (Madejová et al., 2017). For details see Dataset S1.


7200
7174
7065
7020
F VL
Tuff and tuffites
DS3-4
DS2
DS1
M12 (IB 11)
AFZ (IB 29)
AF236 (IB 4)
AF236 (IB 3)
AF172 (IB 24)
B16 (IB 23)
AF80 (IB 22)
AF57 (IB 17)
AF14 (IB 20)
A16
AF09 (IB 15)
AF19 (IB 14)
AP1 (IB 13)
AF103 (IB 12)
M12 (IB 10)
M11 (IB 9)
M09 (IB 8)
AF236 (IB 6)
AF236 (IB 5)
AF153 (IB 2)
AF151 (IB 1)
AF222 (IB 7)
7400
7200
7000
6800
Wavenumber (cm-1)

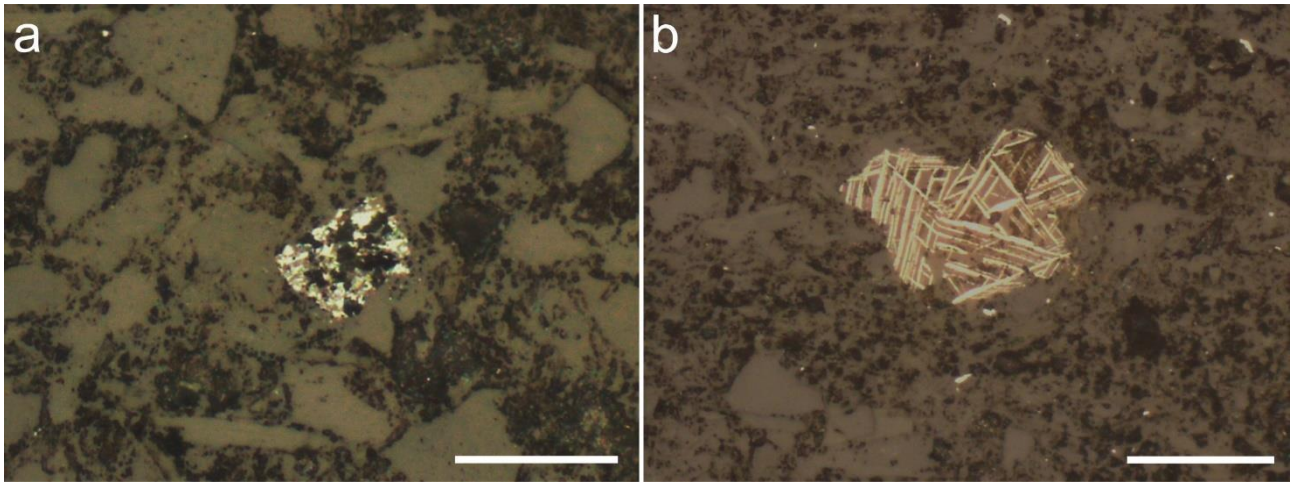
**Supplementary Figure 20**. **Near-Infrared spectra of the clay fractions in the first overtone region (7400–6800 $cm^{-1}$).** The narrow band at 7065 $cm^{-1}$ is attributed to the $2vAl_2OH$ overtone of the OH stretching modes (3620 $cm^{-1}$) of kaolinite (Petit et al., 1999), and the shoulder near 7170 $cm^{-1}$ corresponds to the first overtone of the 3669 $cm^{-1}$ band of kaolinite (Madejová et al., 2017). Changes to higher positions near 7071 $cm^{-1}$ likely reflects the 2v(OH) overtone of illite, present in most of the fossiliferous samples and tuffs. The shoulder near 7020 $cm^{-1}$ could be related to the overtone of the band at 3598 $cm^{-1}$ ($vA1OHFe^{3+}$) of kaolinites with $Fe^{3+}$ substitutions. However, the presence of this shoulder seems to correlate with the presence of kaolinite. For details see Dataset S1.




**Supplementary Figure 21. Statistical comparison of Raman fitting results from fossil clays (red), matrix clays (black) and detrital mica (blue).** (**a)** Scatter plot showing the relationship of full width at half maximum and peak position of fossil and matrix clays. Note that fossil clays present higher FWHM values and lower peak positions, due to the presence of bands of illite (and sometimes quartz) in this region. **(b)** Same as (a), but results from investigations realized in a different day. **(c)** Box plot of the 700/465 $cm^{-1}$ area ratio, showing higher proportion of area of the peak near 700 $cm^{-1}$ (characteristic of phyllosilicates) in the fossils. **(d)** Box plot of the position of the peak near 700 $cm^{-1}$ for the clays in the matrix and the fossils, as well as for micas. Note similar values for fossils and matrix clays. **(e)** FWHM of the peak near 700 $cm^{-1}$ for each type of clay. Note higher FWHM in the spectra from fossil clays and lower values of FWHM for micas, suggesting higher and lower degrees of crystallinity respectively.




**Supplementary Figure 22. EDS maps of a small region inside a three-dimensionally preserved Arumberia-type microbial mat. (a)** electron image. Elemental maps of **(b)** aluminum, **(c)** potassium, **(d)** silicon, **(e)** sodium, **(f)** titanium, highlighting fine-grained anatase concentrations (e.g. arrow), **(g)** iron, and **(h)** oxygen. Scale: 10 µm.




**Supplementary Figure 23. Leucoxene grains**. **(a)** Leucoxene after Fe-Ti oxide mineral (probably ilmenite). **(b)** Leucoxene after titanomagnetite, presenting characteristic trellis texture. Scales: 50 µm.

**Movie 1 (separate file).** Microtomographic movie composed of horizontal sections (bedding plane) of a sample with 3D clay mineralized microbial tufts.

**Dataset 1 (separate file).** Infrared absorption bands of the selected samples (clay fraction)

**Dataset 2 (separate file).** Oxide wt% results and calculated structural formula of illite crystals from fossils

**Dataset 3 (separate file).** Raman fitting results for the fossil and cement/matrix (C/M) clay minerals, and detrital micas

**Dataset 4 (separate file).** Raman spectroscopy polymorph identification in randomly chosen TiO2 crystals from fossils (3D Arumberia mats) and sedimentary matrix

## 6 FINAL CONSIDERATIONS

The Itajaí Basin provides a unique view on the first benthic communities of macroscopic complex organisms from the fossil record. The new radiometric dating for this occurrence suggests that it can be regarded as one of the oldest in Gondwanan deposits. Despite relatively depauperate in its taxonomic composition, the Itajaí biota yields well-known Ediacaran taxa, such as *Palaeopascichnus*. Other forms are also present, such as discoidal morphologies, diverse microbially-related structures, and well-preserved microbial filamentous forms.

Moreover, the filaments are here interpreted as the impressions of large sulphur-oxidizing bacteria, similar to the modern genus *Beggiatoa*. The common occurrence of these filaments with the Ediacaran biota suggest that they could have been important components of these benthic communities. It is possible that they also contributed to the biogeochemical cycles of N, S and C, during Ediacaran times.

The exceptional preservation of the Itajaí biota sheds new light on the ‘Ediacaran-style’ moldic fossilization. In this case, it shows how the complex interplay between volcanic sediments and microbial activity can play a major role in the preservation of the external morphology of soft-bodied organisms. This occurred through an early formation of clays that templated the external surfaces of the Ediacaran organisms.

Finally, this work highlights the great potential of the Itajaí Basin for the studies on the early evolution of complex macroorganisms and animals. Future studies can focus in expanding the now known fossil composition, as well as prospecting other portions of the basin. Importantly, volcaniclastic and pyroclastic sediments can also reveal other exceptionally preserved assemblages in this unity. At the same time, the common occurrence of such deposits provides a good opportunity to improve the age constraints of the basin by U/Pb radiometric dating.

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Supplementary Table 1. Investigated outcrops and respective geographic coordinates

| Outcrop | Coordinates |
|---|---|
| AF1 | 27° 2'38.30"S 49°23'42.70"W |
| AF2 | 27° 4'56.00"S 49°30'42.60"W |
| AF4 | 27° 4'38.70"S 49°29'44.20"W |
| AF6 | 27° 5'46.00"S 49°27'34.80"W |
| AF7 | 27° 5'56.00"S 49°27'35.80"W |
| AF8 | 27° 5'46.11"S 49°27'49.91"W |
| AF9 | 27° 5'0.20"S 49°26'38.07"W |
| AF10 | 27° 6'11.70"S 49°25'27.20"W |
| AF11 | 27° 6'8.30"S 49°25'37.60"W |
| AF12 | 27° 5'56.70"S 49°25'45.20"W |
| AF13 | 27° 5'54.40"S 49°25'49.00"W |
| AF14 | 27° 5'49.40"S 49°25'51.20"W |
| AF15 | 27° 5'47.80"S 49°25'52.90"W |
| AF16 | 27° 5'43.70"S 49°26'0.60"W |
| AF17 | 27° 5'11.60"S 49°26'26.70"W |
| AF18 | 27° 2'23.80"S 49°23'27.20"W |
| AF19 | 27° 2'29.11"S 49°23'32.50"W |
| AF20 | 27° 2'16.00"S 49°23'16.60"W |
| AF21 | 27° 2'15.60"S 49°23'15.80"W |
| AF22 | 27° 2'20.00"S 49°22'53.70"W |
| AF23 | 27° 2'48.70"S 49°21'44.00"W |
| AF24 | 27° 3'7.07"S 49°21'33.30"W |
| AF25 | 27° 3'23.80"S 49°21'18.80"W |
| AF26 | 27° 3'26.00"S 49°21'5.70"W |
| AF27 | 27° 3'48.20"S 49°21'15.10"W |
| AF28 | 27° 4'22.60"S 49°20'17.10"W |
| AF29 | 27° 4'58.60"S 49°20'10.70"W |
| AF30 | 27° 5'17.70"S 49°19'56.60"W |
| AF31 | 27° 2'3.90"S 49°22'56.80"W |
| AF32 | 27° 7'56.80"S 49°19'31.00"W |
| AF33 | 27° 9'1.20"S 49°19'22.20"W |
| AF34 | 27° 9'2.80"S 49°19'13.30"W |
| AF36 | 27° 9'33.80"S 49°19'2.20"W |
| AF37 | 27° 9'48.10"S 49°18'59.40"W |
| AF38 | 26°59'7.80"S 49°22'13.20"W |
| AF39 | 26°59'10.50"S 49°22'10.70"W |
| AF40 | 26°59'21.70"S 49°22'9.90"W |
| AF41 | 26°59'24.60"S 49°21'56.60"W |
| AF42 | 26°59'36.80"S 49°21'30.40"W |
| AF43 | 26°59'52.50"S 49°21'12.30"W |
| AF44 | 27° 0'2.90"S 49°21'8.10"W |
| AF45 | 27° 0'9.30"S 49°20'56.00"W |
| AF46 | 27° 0'8.70"S 49°20'53.70"W |
| AF47 | 27° 0'7.70"S 49°20'50.70"W |
| AF48 | 27° 0'15.40"S 49°20'32.90"W |
| AF49 | 27° 0'18.80"S 49°20'28.50"W |
| AF50 | 27° 0'23.00"S 49°20'23.80"W |
| AF51 | 27° 0'15.00"S 49°20'37.00"W |
| AF52 | 27° 0'19.70"S 49°20'33.50"W |

Appendix I - Supplementary Table 1. *Cont.*

| | |
|---|---|
| AF53 | 27° 0'27.80"S 49°20'31.30"W |
| AF54 | 27° 0'41.00"S 49°20'25.00"W |
| AF55 | 27° 0'48.10"S 49°20'19.70"W |
| AF56 | 27° 1'9.90"S 49°20'24.70"W |
| AF57 | 27° 1'18.00"S 49°20'12.40"W |
| AF58 | 27° 0'46.90"S 49°22'12.20"W |
| AF59 | 27° 0'53.50"S 49°22'7.20"W |
| AF60 | 27° 1'8.90"S 49°21'50.00"W |
| AF61 | 27° 1'15.70"S 49°21'37.00"W |
| AF62 | 27° 1'25.73"S 49°21'16.11"W |
| AF63 | 27° 1'30.38"S 49°21'10.78"W |
| AF64 | 27° 1'31.70"S 49°21'3.10"W |
| AF65 | 27° 1'31.40"S 49°20'57.80"W |
| AF66 | 27° 1'33.90"S 49°20'52.20"W |
| AF67 | 27° 1'35.10"S 49°20'50.10"W |
| AF68 | 27° 1'39.30"S 49°20'45.00"W |
| AF69 | 27° 1'40.90"S 49°20'40.10"W |
| AF70 | 27° 1'50.60"S 49°20'34.20"W |
| AF71 | 27° 1'53.90"S 49°20'29.00"W |
| AF72 | 27° 1'59.50"S 49°20'18.80"W |
| AF73 | 27° 1'34.30"S 49°20'56.80"W |
| AF74 | 27° 1'34.90"S 49°20'54.40"W |
| AF75 | 27° 1'47.70"S 49°20'57.90"W |
| AF76 | 27° 2'22.00"S 49°20'33.40"W |
| AF77 | 27° 7'8.90"S 49°26'59.60"W |
| AF78 | 27° 7'26.00"S 49°26'51.40"W |
| AF79 | 27° 7'37.00"S 49°26'43.70"W |
| AF80 | 27° 7'38.50"S 49°26'43.80"W |
| AF81 | 27° 7'44.90"S 49°26'47.80"W |
| AF82 | 27° 7'48.70"S 49°26'48.20"W |
| AF83 | 27° 8'4.60"S 49°27'0.40"W |
| AF84 | 27° 8'25.30"S 49°27'23.20"W |
| AF85 | 27° 8'1.90"S 49°27'22.90"W |
| AF86 | 27° 7'7.50"S 49°25'52.60"W |
| AF87 | 27° 7'9.30"S 49°25'51.00"W |
| AF88 | 27° 7'11.80"S 49°25'41.90"W |
| AF89 | 27° 7'25.40"S 49°25'20.40"W |
| AF90 | 27° 7'29.60"S 49°25'15.30"W |
| AF91 | 27° 7'36.80"S 49°25'3.60"W |
| AF92 | 27° 7'25.70"S 49°24'42.10"W |
| AF93 | 27° 7'15.10"S 49°24'29.60"W |
| AF94 | 27° 2'1.00"S 49°23'35.80"W |
| AF95 | 27° 2'7.10"S 49°23'51.40"W |
| AF96 | 27° 1'58.10"S 49°24'4.50"W |
| AF97 | 27° 2'11.80"S 49°23'48.40"W |
| AF98 | 27° 2'9.60"S 49°24'7.50"W |
| AF99 | 27° 3'5.00"S 49°23'34.40"W |
| AF100 | 27° 3'12.09"S 49°23'34.20"W |
| AF101 | 27° 3'17.70"S 49°23'35.60"W |
| AF102 | 27° 1'41.02"S 49°23'21.80"W |

Appendix I - Supplementary Table 1. *Cont.*

| | |
|---|---|
| AF103 | 27° 1'19.40"S 49°22'55.40"W |
| AF104 | 27° 0'44.30"S 49°22'40.60"W |
| AF105 | 27° 0'36.70"S 49°22'42.70"W |
| AF106 | 27° 0'3.20"S 49°22'45.40"W |
| AF107 | 26°59'14.70"S 49°23'7.00"W |
| AF108 | 26°58'59.80"S 49°22'48.10"W |
| AF109 | 26°58'57.90"S 49°22'46.10"W |
| AF111 | 26°57'13.60"S 49°19'35.60"W |
| AF113 | 26°57'11.30"S 49°10'36.30"W |
| AF114 | 26°57'56.80"S 49°10'40.50"W |
| AF115 | 26°58'3.80"S 49°10'44.40"W |
| AF116 | 26°58'14.60"S 49°10'34.70"W |
| AF117 | 26°59'10.10"S 49°10'55.60"W |
| AF118 | 26°59'6.60"S 49°10'59.90"W |
| AF119 | 26°59'30.60"S 49°11'22.00"W |
| AF120 | 26°59'32.20"S 49°11'19.60"W |
| AF121 | 26°59'38.50"S 49°11'20.60"W |
| AF122 | 26°59'54.60"S 49°11'33.30"W |
| AF123 | 26°59'53.40"S 49°11'35.30"W |
| AF124 | 26°59'48.80"S 49°11'44.60"W |
| AF125 | 26°59'49.50"S 49°11'46.80"W |
| AF126 | 26°59'50.50"S 49°11'51.80"W |
| AF127 | 26°59'56.60"S 49°12'2.30"W |
| AF128 | 27° 7'14.60"S 49°26'3.95"W |
| AF129 | 27° 7'43.40"S 49°25'45.40"W |
| AF130 | 27° 7'55.80"S 49°25'37.50"W |
| AF131 | 27° 8'0.20"S 49°25'37.30"W |
| AF132 | 27° 8'3.20"S 49°25'35.60"W |
| AF133 | 27° 8'17.60"S 49°25'22.50"W |
| AF134 | 27° 8'20.10"S 49°25'24.50"W |
| AF135 | 27° 8'31.80"S 49°25'26.60"W |
| AF136 | 27° 8'41.70"S 49°25'22.50"W |
| AF137 | 27° 9'1.00"S 49°25'1.70"W |
| AF138 | 27° 9'11.40"S 49°24'55.20"W |
| AF139 | 27° 9'16.60"S 49°25'1.70"W |
| AF143 | 27° 8'30.80"S 49°20'24.30"W |
| AF144 | 27° 8'24.20"S 49°20'0.70"W |
| AF145 | 27° 8'10.70"S 49°19'38.40"W |
| AF146 | 27° 7'59.10"S 49°19'32.30"W |
| AF147 | 26°53'26.50"S 48°53'9.70"W |
| AF148 | 26°53'36.30"S 48°53'49.40"W |
| AF149 | 26°49'5.40"S 48°47'5.50"W |
| AF150 | 26°48'58.80"S 48°47'23.90"W |
| AF151 | 26°57'47.50"S 49°21'29.20"W |
| AF152 | 26°57'53.70"S 49°20'52.30"W |
| AF153 | 26°58'0.70"S 49°20'10.80"W |
| AF154 | 26°57'34.00"S 49°18'48.70"W |
| AF155 | 26°57'18.50"S 49°18'50.40"W |
| AF156 | 26°58'25.50"S 49°15'40.70"W |
| AF157 | 26°58'26.20"S 49°15'0.90"W |

Appendix I - Supplementary Table 1. *Cont.*

| | |
|---|---|
| AF158 | 26°57'55.40"S 49°14'6.60"W |
| AF159 | 26°57'53.70"S 49°14'3.30"W |
| AF161 | 27° 4'36.00"S 49°24'38.10"W |
| AF162 | 27° 8'1.70"S 49°26'16.90"W |
| AF163 | 27° 2'36.60"S 49°22'17.50"W |
| AF164 | 27° 2'37.40"S 49°22'25.40"W |
| AF165 | 27° 4'42.00"S 49°21'21.80"W |
| AF166 | 27° 4'54.50"S 49°21'18.60"W |
| AF167 | 27° 5'7.90"S 49°21'24.90"W |
| AF168 | 27° 5'35.10"S 49°21'46.50"W |
| AF169 | 27° 5'42.90"S 49°21'51.50"W |
| AF170 | 27° 6'6.80"S 49°22'26.30"W |
| AF171 | 27° 6'30.90"S 49°23'4.00"W |
| AF172 | 27° 6'38.30"S 49°23'5.00"W |
| AF173 | 27° 6'57.80"S 49°23'4.20"W |
| AF174 | 27° 7'16.20"S 49°22'59.60"W |
| AF175 | 26°58'59.90"S 49°24'34.10"W |
| AF176 | 26°59'38.80"S 49°26'4.60"W |
| AF177 | 26°59'39.40"S 49°26'8.10"W |
| AF178 | 26°59'46.90"S 49°27'12.30"W |
| AF179 | 26°59'48.10"S 49°27'31.70"W |
| AF180 | 26°56'4.30"S 49° 3'39.40"W |
| AF181 | 27° 0'19.80"S 49° 4'5.50"W |
| AF183 | 26°58'22.60"S 49°16'53.00"W |
| AF184 | 26°59'31.40"S 49°16'5.00"W |
| AF189 | 27° 4'36.30"S 49°19'26.60"W |
| AF190 | 27° 4'40.30"S 49°19'23.30"W |
| AF191 | 27° 4'44.50"S 49°19'11.70"W |
| AF192 | 27° 4'49.20"S 49°19'3.60"W |
| AF193 | 27° 4'44.60"S 49°18'40.70"W |
| AF194 | 27° 4'45.80"S 49°18'33.30"W |
| AF195 | 27° 5'5.80"S 49°18'8.90"W |
| AF196 | 27° 5'38.70"S 49°18'3.20"W |
| AF197 | 27° 5'57.90"S 49°17'56.60"W |
| AF198 | 27° 6'17.20"S 49°17'39.20"W |
| AF199 | 27° 6'19.00"S 49°17'36.90"W |
| AF200 | 27° 6'20.40"S 49°17'37.40"W |
| AF201 | 27° 6'23.40"S 49°17'34.10"W |
| AF202 | 27° 6'31.30"S 49°17'29.10"W |
| AF203 | 27° 6'48.80"S 49°17'17.50"W |
| AF204 | 27° 6'48.40"S 49°17'13.20"W |
| AF205 | 27° 4'28.50"S 49°25'23.90"W |
| AF206 | 27° 4'40.90"S 49°25'17.10"W |
| AF207 | 27° 4'56.40"S 49°25'11.40"W |
| AF208 | 27° 4'57.70"S 49°24'57.00"W |
| AF209 | 27° 4'59.90"S 49°24'44.10"W |
| AF210 | 27° 5'1.00"S 49°24'39.60"W |
| AF211 | 27° 5'5.10"S 49°24'36.10"W |
| AF212 | 27° 5'13.50"S 49°24'25.20"W |
| AF213 | 27° 5'16.90"S 49°24'22.60"W |

Appendix I - Supplementary Table 1. *Cont.*

| | |
|---|---|
| AF214 | 27° 5'21.00"S 49°24'21.30"W |
| AF215 | 27° 5'23.40"S 49°24'19.00"W |
| AF216 | 27° 5'35.10"S 49°24'6.60"W |
| AF217 | 26°57'50.40"S 49°19'3.70"W |
| AF218 | 27° 5'35.60"S 49°26'10.60"W |
| AF219 | 27° 5'45.50"S 49°25'54.60"W |
| AF220 | 26°52'44.30"S 48°50'35.90"W |
| AF221 | 26°52'18.90"S 48°50'19.80"W |
| AF222 | 26°52'15.10"S 48°50'29.50"W |
| AF223 | 26°51'52.00"S 48°50'33.40"W |
| AF224 | 26°51'23.30"S 48°50'51.80"W |
| AF225 | 26°50'58.90"S 48°51'57.00"W |
| AF226 | 26°51'0.00"S 48°54'19.70"W |
| AF227 | 26°50'54.00"S 48°54'52.50"W |
| AF228 | 26°50'28.50"S 48°54'48.30"W |
| AF229 | 26°50'23.00"S 48°55'8.10"W |
| AF231 | 26°59'22.10"S 49°25'9.30"W |
| AF232 | 27° 3'7.00"S 49°24'12.60"W |
| AF233 | 27° 3'8.60"S 49°24'25.90"W |
| AF234 | 27° 2'39.50"S 49°24'57.20"W |
| AF235 | 27° 2'34.20"S 49°24'58.20"W |
| AF236 | 27° 2'29.10"S 49°25'7.40"W |
| AF237 | 27° 2'25.70"S 49°25'20.30"W |
| AF238 | 27° 2'24.10"S 49°25'24.60"W |
| AF239 | 27° 2'21.60"S 49°25'33.40"W |
| AF240 | 27° 3'6.80"S 49°24'11.70"W |
| AF241 | 27° 3'13.50"S 49°25'25.10"W |
| AF242 | 27° 3'14.00"S 49°25'31.20"W |
| BERG | 27° 4'6.81"S 49°25'8.98"W |
| AF Z | 27° 9'27.08"S 49°19'2.54"W |
| AF H | 27° 2'34.62"S 49°21'54.00"W |
| M9 | 26°54'52.05"S 48°58'7.15"W |
| M11 | 26°54'54.75"S 48°58'11.27"W |
| M12 | 26°55'1.20"S 48°58'8.90"W |
| A16 | 27° 5'46.62"S 49°25'51.43"W |

## Supplementary Table 1. Database of thesize ranges of modern unbranched filamentous organisms

| phylum | class | order | family | spp | fil_width_min | fil_width_max | trich_width_min | trich_width_max | cell_width_min | cell_width_max | cell_length_min | cell_length_max | fil_length_min | fil_length_max | ref |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | "Candidatus Maribeggiatoa vulgaris" (Attached filaments) | 4 | 112 | 4 | 112 | 4 | 112 | | | | | [1] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | Beggiatoaceae | 18 | 28 | | | | | | | | | [2] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 116 | 122 | 116 | 122 | 116 | 122 | | | | | [3] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 6 | 200 | 6 | 200 | 6 | 200 | | | | 20.000,0 | [4] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | | 6,3 | | 6,3 | | 6,3 | | | | | [5] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 5 | 35 | 5 | 35 | 5 | 35 | | | | | [5] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 8 | 10 | 8 | 10 | 8 | 10 | | | | | [5] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 3 | 4 | 3 | 4 | 3 | 4 | | | | | [6] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 40 | 45 | 40 | 45 | 40 | 45 | | | | | [7] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | | 120 | | 120 | | 120 | | | 2.000,0 | 10.000,0 | [7] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 35 | 40 | 35 | 40 | 35 | 40 | | | | | [8] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 30 | 50 | 30 | 50 | 30 | 50 | | | | | [9] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 88 | 108 | 88 | 108 | 88 | 108 | | | | | [9] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | | 200 | | 200 | | 200 | | | Several cms | | [10] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 20 | 30 | 20 | 30 | 20 | 30 | | | | | [11] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 32,5 | 50 | 32,5 | 50 | 32,5 | 50 | | | | | [11] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 80 | 160 | 80 | 160 | 80 | 160 | | | | | [11] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 22,5 | 40 | 22,5 | 40 | 22,5 | 40 | | | | | [11] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 65 | 85 | 65 | 85 | 65 | 85 | 5 | 36 | 10.000,0 | 100.000,0 | [12] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 88 | 140 | 88 | 140 | 88 | 140 | | | | | [12] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 20 | 35 | 20 | 35 | 20 | 35 | | | | | [11] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 80 | 160 | 80 | 160 | 80 | 160 | | | | | [11] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 3 | 5 | 3 | 5 | 3 | 5 | | | | 800,0 | [13] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 5 | 23 | 5 | 23 | 5 | 23 | | | | 1.000,0 | [13] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 23 | 35 | 23 | 35 | 23 | 35 | | | | 1.900,0 | [13] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 20 | 76 | 20 | 76 | 20 | 76 | | | | | [1] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 20 | 95 | 20 | 95 | 20 | 95 | | | | | [14] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 20 | 65 | 20 | 65 | 20 | 65 | | | | | [14] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 1 | 40 | 1 | 40 | 1 | 40 | | | 100,0 | 10.000,0 | [15] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *"Candidatus Maribeggiatoa vulgaris" (Beggiatoa sp)* | 65 | 85 | 65 | 85 | 65 | 85 | | | | | [16] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *"Candidatus Isobeggiatoa divolgata" (Beggiatoa sp.)* | 9 | 11 | 9 | 11 | 9 | 11 | | | | | [17] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa sp.* | 5,3 | 31 | 5,3 | 31 | 5,3 | 31 | | | | | [18] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *"Candidatus Parabeggiatoa" (Beggiatoa spp)* | 5 | 30 | 5 | 30 | 5 | 30 | | | | | [17] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa spp.* | 5 | 8 | 5 | 8 | 5 | 8 | | | | | [19] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *"Candidatus Isobeggiatoa divolgata" (Beggiatoa spp.)* | 2 | 5 | | | | 3,7 | | 5,4 | | 250,0 | [20] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *"Candidatus Isobeggiatoa divolgata" Beggiatoa spp.* | 11 | 22 | | | | 19 | | 9 | | | [20] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *"Candidatus Isobeggiatoa divolgata" Beggiatoa spp.* | 23 | 50 | | | | | | | | 1.500,0 | [20] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *"Candidatus Isobeggiatoa divolgata" (Beggiatoa spp).* | 10 | 30 | 10 | 30 | 10 | 30 | | | | | [21] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Beggiatoa spp.* | 6 | 8 | 6 | 8 | 6 | 8 | | | 1.000,0 | 10.000,0 | [22] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *"Candidatus Marithrix sp."* | | 110 | | 110 | | 110 | | | | | [23] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | Large filamentous bacteria | 20 | 30 | 20 | 30 | 20 | 30 | | | | | [24] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | Large filamentous bacteria | 40 | 60 | 40 | 60 | 40 | 60 | | | | | [24] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | Large filamentous bacteria | | 135 | | 135 | | 135 | | | | | [24] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Morphotype 1* | | 60 | | 60 | | 60 | | 18,6 | | 30.000,0 | [25] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Morphotype 2* | | 30 | | 30 | | 30 | | 3,8 | | | [25] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | Sheathless trichomes | | | 50 | 60 | | | | | | | [26] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Thioploca* | 21,5 | 89,1 | 1,5 | 4,2 | | | 1 | 5,7 | | | [27] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Thioploca* | 10,4 | 65,3 | 2,2 | 10,7 | | | 1,37 | 11,1 | | | [27] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Thioploca* | 10,8 | 124,6 | 1,6 | 7,4 | | | 1,2 | 8,9 | | | [27] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Thioploca* | 233,4 | 234 | 1,4 | 9,4 | | | 1 | 11,9 | | | [27] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Thioploca* | | | 6,5 | 10,5 | | | | | | | [27] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Thioploca* | 100 | 200 | | | | | | | | | [27] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Thioploca* | 17 | 28 | 2 | 4,3 | | | | | | | [27] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Thioploca* | | | 2,6 | 5,8 | | | | | | | [28] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Thioploca* | | | 3 | 4 | | | | | | | [29] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Thioploca* | 28,5 | 42,5 | 12 | 15 | | | | | 4.000,0 | 8.000,0 | [151] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Thioploca* | 50 | 400 | 3 | 75 | | | | | | 20.000,0 | [30] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Thioploca ingrica* | 30 | 126 | | 3,8 | | | | | 22.000,0 | 56.000,0 | [31] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Thiolava veneris* | 30 | 90 | 3 | 6 | 3 | 6 | | | | 30.000,0 | [32] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *"Candidatus Marithioploca" (Thioploca araucae)* | | | 28 | 42 | | | | | | | [26] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *"Candidatus Marithioploca" (Thioploca araucae)* | | | 30 | 40 | 30 | 40 | | | | | [33] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *"Candidatus Marithioploca" (Thioploca araucae)* | | | 30 | 43 | | | 11 | 36 | | | [341] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *"Candidatus Marithioploca" (Thioploca chilaea)* | | | 12 | 20 | | | 7 | 26 | | | [34] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *"Candidatus Marithioploca" (Thioploca chilaea)* | | 100 | 15 | 20 | 15 | 20 | | | | | [33] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *"Candidatus Marithioploca" (Thioploca chilaea)* | 12 | 22 | | | | | | | | | [26] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *"Candidatus Marithioploca" (Thioploca spp)* | 100 | 500 | 2,5 | 40 | 2,5 | 40 | | | Several cms | | [35] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *"Thioploca marina"* | 1 | 8 | | | | | | | | | [26] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Thioploca schmidlev* | 50 | 160 | 5 | 9 | | | | | | | [36] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Thioploca spp* | 15 | 80 | 4 | | 4 | | | | | 50.000,0 | [37] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Thioploca sp* | | | 60 | 125 | | | | | | | [38] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Thioploca* sheaths | 50 | 500 | | | | | | | | 100.000,0 | [38] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Thiothrix nivea* | | | | | 1,5 | 3 | 1,5 | 3 | | | [39] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | *Thiothrix sp* | | 1,5 | | | | | | | | | [19] |
| PROTEOBACTERIA | Gammaproteobacteria | Thiotrichales | Thiotrichaceae | "Candidatus Marithrix sessilis" | 9 | 96 | 9 | 96 | 9 | 96 | | | | | [40] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Coleofasciculaceae | *Anagnostidinema acutissimum* | | | 1,5 | 2,5 | | | 3 | 7 | | | [41][42][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Coleofasciculaceae | *Anagnostidinema amphibium* | | | | | 1,5 | 3 | 3 | 9 | | | [41][44] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Coleofasciculaceae | *Anagnostidinema ionicum* | | | | | 1 | 1,3 | 2 | 5,5 | | | [41][42][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Coleofasciculaceae | *Anagnostidinema lemmermannii* | | | | | 2 | 2,5 | 4 | 6 | | | [41][42][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Coleofasciculaceae | *Geitlerinema aculforme* | | | 0,7 | 0,9 | | | 3,5 | 6,5 | | | [41][42][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Coleofasciculaceae | *Geitlerinema numidicum* | | | 2,3 | 4 | | | 2,8 | 6,5 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Coleofasciculaceae | *Geitlerinema spleidum* | | | 1,8 | 3,1 | | | 3 | 9 | | 1.000,0 | [41][43][44] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | incertae sedis | *Jaaginema pseudogeminatum* | | | 1,3 | 2,2 | | | 2 | 2,6 | | | [41][45][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Microcoleaceae | *Kamptonema animale* | | | 1,3 | 4 | | | 1,5 | 5 | | | [41][43][46] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Microcoleaceae | *Kamptonema chlorinum* | | | 3,5 | 4 | | | 3,7 | 8 | | | [41][43][46] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Microcoleaceae | *Arthrospira jenneri* | | | 4 | 6 | | | 2 | 6 | | | [41][43][47] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Microcoleaceae | *Arthrospira khannae* | | | | | 3 | 5,2 | 1 | 1,7 | | | [41][45][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Microcoleaceae | *Arthrospira platensis* | | | 6 | 7 | | | 2 | 6 | | 1.150,0 | [41][45][43][48] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Microcoleaceae | *Kamptonema formosum* | | | 4 | 5,5 | | | 3 | 4,5 | | | [41][49] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Microcoleaceae | *Microcoleus amoenus* | | | 2,5 | 5 | | | 2,5 | 4,2 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Microcoleaceae | *Microcoleus autumnalis* | | | | | 3,4 | 4,4 | 1,9 | 3,8 | | | [41][50][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Microcoleaceae | *Microcoleus setchellianus* | | | 4 | 6,5 | | | 3 | 6,6 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Microcoleaceae | *Microcoleus subtorulosus* | 13,2 | 20 | | | 6 | 10 | 3 | 10 | | | [41][45][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Microcoleaceae | *Planktothrix rubescens* | | | 6 | 8 | | | 2 | 4 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Microcoleaceae | *Porphyrosiphon versicolor* | | | | | 2,8 | 3,2 | 2 | 6,5 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Microcoleaceae | *Symploca elegans* | | | 1,3 | 2 | | | 2 | 4 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Microcoleaceae | *Symploca flaccida* | | | 4 | 5 | | | 1,3 | 2,5 | | | [45] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Microcoleaceae | *Symploca muralis* | | | | | 3,4 | 4 | 2,5 | 5,5 | | 2.500,0 | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Microcoleaceae | *Symploca muscorum* | | 9 | | | 4,5 | 8 | 5 | 11 | | 3.000,0 | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Microcoleaceae | *Symploca parietina* | | | | | 1,5 | 3 | 3,5 | 9,2 | | | [41][45][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Microcoleaceae | *Trichodesmium clevei* | | | 6,3 | 7,7 | | | 6,3 | 15,4 | | 2.000,0 | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Microcoleaceae | *Trichodesmium erythraeum* | | | 7 | 11 | | | 5,4 | 11 | | 1.000,0 | [41][43][51] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Microcoleaceae | *Trichodesmium iwanoffianum* | 50 | 100 | 7 | 8 | | | 2 | 5 | 650,0 | 900,0 | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Microcoleaceae | *Trichodesmium lacustre* | | | | | 4 | 7 | 3 | 6 | | 550,0 | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Microcoleaceae | *Trichodesmium thiebautii* | | | 7 | 16 | | | 8 | 26 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Oscillatoria iica* | | | | | 4 | 4,5 | 1,5 | 2 | | | [41][45][52] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Phormidium acula* | | | 4 | 6 | | | 3 | 4 | | | [41][45][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Phormidium grunowianum* | | | 3,7 | 5,6 | | | 1,4 | 4 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Limnoraphis cryptovaginata* | 7 | 9,2 | | | 4 | 9 | | | | | [41][45][53] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Lyngbya borgertii* | 2,6 | 3 | | | 2 | 2,5 | 2,6 | 5 | | | [41][45] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Lyngbya major* | 20 | 22 | | | 11 | 16 | 2 | 3,4 | | | [41][45][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Lyngbya majuscula* | | | 15 | 60 | | | 2 | 4 | 300.000,0 | 400.000,0 | [41][43][54] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Lyngbya martensiana* | 7 | 12 | 5,6 | 10 | | | 1,5 | 3,5 | | 3.000,0 | [41][43][45] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Lyngbya nigra* | 10 | 14,5 | 8 | 11 | | | 2 | 4 | | 10.000,0 | [41][43][45] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Lyngbya semiplena* | 7 | 15 | 7 | 10 | | | 2 | 3 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Lyngbya sordida* | | | 20 | 31 | | | 4 | 5 | | | [41][43][55] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Lyngbya spiralis* | 5 | 6,5 | 4,5 | 5 | | | 1,5 | 2,5 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Oscillatoria anguina* | | | | | 5,5 | 8,5 | 1,3 | 2,5 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Oscillatoria curviceps* | | | | | 10 | 17 | 2 | 5 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Oscillatoria jenensis* | | | 14 | 26 | | | 3 | 6,5 | 3.000,0 | 7.000,0 | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Oscillatoria limosa* | | | | | 10 | 20 | 1,5 | 5 | | 4.000,0 | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Oscillatoria miniata* | | | | | 16 | 24 | 7 | 11 | | | [41][45][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Oscillatoria princeps* | | | | | 20 | 50 | 2,5 | 6,5 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Oscillatoria tenuis* | | | | | 6 | 11 | 2 | 3,5 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Oscillatoria trichoides* | | | | | 1 | 1,5 | 2 | 9 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Phormidium ambiguum* | 4,5 | 7,5 | 4 | 6 | | | 1,5 | 3,4 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Phormidium articulatum* | | | | | 2,8 | 4 | 1,4 | 4 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Phormidium bohneri* | 3 | 3,7 | | | 2,2 | 2,8 | 1,6 | 2,8 | | | [45] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Phormidium breve* | | | | | 4 | 6,5 | 1,5 | 3 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Phormidium chalybeum* | | | 7 | 8,5 | | | 3,5 | 7 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Phormidium diguetii* | 2,3 | 3 | 2 | 3 | | | 1,8 | 2,8 | | 1.500,0 | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Phormidium favosum* | | | 4,5 | 7,5 | | | 3 | 7 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Phormidium incrustatum* | | | | | 3 | 6,5 | 2,3 | 5,6 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Phormidium inuatum* | | | | | 3 | 5 | 3,3 | 8 | | | [41][43] |

Appendix II - Supplementary Table 1. *Cont.*

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Phormidium irriguum* | | | | | 6 | 11,2 | 4 | 11 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Phormidium lucidum* | | | | | 6 | 8 | 2 | 2,5 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Phormidium nigrum* | | | 6 | 8,5 | | | 1,8 | 2,8 | | | [41][43][56] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Phormidium retzii* | | | | | 4,5 | 12 | 3,2 | 9 | | | [41][43][50] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Phormidium rubidum* | 6 | 7 | 4 | 4,5 | | | 7,5 | 12 | | 3.000,0 | [41][45][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Phormidium schultzii* | | | | | 1 | 2,6 | 1,5 | 4 | | | [57] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Phormidium stagninum* | 8 | 12 | 7 | 10 | | | 2 | 4 | | | [41][43][58] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Phormidium subfuscum* | | | | | 8 | 11,5 | 2 | 8 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Phormidium subincrustatum* | 6,2 | 7,7 | | | 4,3 | 4,6 | 1,5 | 3,1 | | | [41][59][45] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Phormidium terebriforme* | | | | | 4 | 6,5 | 2,4 | 6 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Phormidium tergestinum* | | | | | 4 | 10 | 2,4 | 6,5 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Oscillatoriales | Oscillatoriaceae | *Phormidium uncinatum* | | | | | 5,5 | 9 | 2 | 6 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Spirulinales | Spirulinaceae | *Glaucospira laxissima* | | | | | 0,5 | 0,6 | 2,7 | 6,1 | 36,8 | 100,0 | [41][60][43] |
| CYANOBACTERIA | Cyanophyceae | Spirulinales | Spirulinaceae | *Spirulina corakiana* | | | | | 0,7 | 0,8 | | | 25,0 | 70,0 | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Spirulinales | Spirulinaceae | *Spirulina major* | | | | | 1 | 2 | | | 300,0 | 800,0 | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Spirulinales | Spirulinaceae | *Spirulina meneghiniana* | | | | | 1,2 | 1,8 | | | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Spirulinales | Spirulinaceae | *Spirulina spirulinoides* | | | | | 5 | 6 | 4 | 12 | | 60,0 | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Spirulinales | Spirulinaceae | *Spirulina subtilissima* | | | | | 0,5 | 1 | | | 10,0 | 20,0 | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Spirulinales | Spirulinaceae | *Spirulina tenerrima* | | | | | 0,3 | 0,6 | | | 30,0 | 65,0 | [41][43][61] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Aphanizomenonaceae | *Anabaenopsis elenkinii* | | | | | 4 | 6 | 4 | 9 | | 100,0 | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Aphanizomenonaceae | *Aphanizomenon flosaquae* | | | | | 5 | 6 | 5 | 15 | | 2.000,0 | [41][51] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Aphanizomenonaceae | *Nodularia harveyana* | 4 | 7,5 | | | 3,5 | 7,2 | 1,5 | 7,2 | | | [41][62] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Aphanizomenonaceae | *Nodularia spumigena* | 8 | 16 | | | 7,5 | 16 | 0,7 | 8 | | | [41][62][51] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Nostocaceae | *Anabaena inaequalis* | | | | | 4 | 5,3 | 4.0 | 6 | | | [41][51][63] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Nostocaceae | *Anabaena catenula* | | | | | 5 | 8 | | | | | [41][51] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Nostocaceae | *Anabaena cylirica* | | | | | 3 | 4 | 5 | 7 | | | [41][51] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Nostocaceae | *Anabaena felisii* | | | | | 5,8 | 7 | 6 | 10 | | | [41][42] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Nostocaceae | *Anabaena oscillarioides* | | | | | 3 | 6 | 4 | 6 | | | [41][64] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Nostocaceae | *Anabaena saaremaaensis* | | | | | 4,8 | 5,5 | 4,6 | 8,7 | | | [41][42] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Nostocaceae | *Anabaena sphaerica* | | | | | 5 | 6,2 | 5 | 6,2 | | | [41][42] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Nostocaceae | *Cylirospermum licheniforme* | | | | | 2,5 | 4,2 | 4 | 5 | | | [41][45] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Nostocaceae | *Cylirospermum majus* | | | | | 4 | 5 | 5 | 6 | | | [41][45] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Nostocaceae | *Cylirospermum stagnale* | | | | | 4 | 4,8 | 4 | 6,6 | | | [41][42] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Rivulariaceae | *Calothrix atricha* | | | | | 6 | 8 | | | | 100,0 | [41][42] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Rivulariaceae | *Calothrix breviarticulata* | 15 | 16 | | | 5,5 | 7,5 | 1,3 | 3,8 | | 380,0 | [41][45] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Rivulariaceae | *Calothrix brevissima* | | | | | 6,5 | 8 | 5 | 7,5 | 53,0 | 94,0 | [41][57][45] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Rivulariaceae | *Calothrix clavata* | | | | | 4 | 6 | 3 | 7 | | 100,0 | [41][64][45] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Rivulariaceae | *Calothrix epiphytica* | 5 | 7,5 | | | 3 | 3,6 | 6 | 8,4 | 250,0 | 350,0 | [41][65][45][66] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Rivulariaceae | *Calothrix kossinskajae* | | | | | 3,5 | 6 | | | | 160,0 | [41][42] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Rivulariaceae | *Calothrix linearis* | 4 | 12 | | | 3 | 9,5 | 2,5 | 5 | | 450,0 | [41][67] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Rivulariaceae | *Calothrix marchica* | | | | | 9 | 10 | 6 | 9 | | | [41][49] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Rivulariaceae | *Calothrix parietina* | | | | | 4,5 | 10,5 | 5 | 12,5 | 250,0 | 1.000,0 | [41][64][45] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Rivulariaceae | *Calothrix pulvinata* | 7 | 12 | | | 5 | 10 | 3 | 6 | 2.000,0 | 3.000,0 | [41][68][51] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Rivulariaceae | *Calothrix stagnalis* | 8 | 10 | | | 5 | 9 | 5 | 7 | | 1.000,0 | [41][69][51] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Rivulariaceae | *Microchaete elongata* | | | | | 11 | 14 | 33 | 42 | | | [42] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Rivulariaceae | *Microchaete investiens* | 8,5 | 9 | 5.0 | 5,6 | | | | | | | [41][70] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Rivulariaceae | *Microchaete tenera* | 6 | 7 | 4,5 | 5 | | | 5 | 10 | | 1.000,0 | [41][51][45] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Rivulariaceae | *Rivularia aquatica* | | | 8,4 | 9,6 | | | 0,8 | 1,2 | | 3.500,0 | [41][45][71] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Rivulariaceae | *Rivularia beccariana* | 7 | 9 | 4,8 | 6 | | | 12 | 18 | | | [41][45][71] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Rivulariaceae | *Rivularia bullata* | | | 5 | 8 | | | 10 | 16 | | | [41][51] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Rivulariaceae | *Rivularia dura* | | | 4 | 9 | | | | | | | [41][72] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Rivulariaceae | *Rivularia hansgirgi* | | | 2,8 | 3,5 | | | 3,7 | 5 | | | [41][45][73] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Rivulariaceae | *Rivularia manginii* | 10 | 30 | 3 | 5 | | | 1 | 1,5 | | | [41][45] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Tolypothrichaceae | *Tolypothrix lanata* | | | | | 9 | 11 | 4,5 | 8 | | | [41][74] |
| CYANOBACTERIA | Cyanophyceae | Nostocales | Scytonemataceae | *Heteroscytonema crispum* | 22,8 | 27,8 | | | 17,7 | 22,8 | 3,8 | 6,3 | | 4.000,0 | [41][58] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Pseudanabaenaceae | *Pseudanabaena catenata* | | | | | 1,2 | 2 | 2 | 6 | 40,0 | 200,0 | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Pseudanabaenaceae | *Pseudanabaena acicularis* | | | | | 1 | 1,5 | 8 | 12 | 20,0 | 75,0 | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Pseudanabaenaceae | *Pseudanabaena arcuata* | | | 5 | 7 | | | 2 | 14 | 10,0 | 20,0 | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Pseudanabaenaceae | *Pseudanabaena batrachospermorum* | | | 0,6 | 1,5 | | | 3 | 8 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Pseudanabaenaceae | *Pseudanabaena limnetica* | | | 1,2 | 1,5 | | | 4 | 12 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Pseudanabaenaceae | *Pseudanabaena lonchoides* | | | 0,6 | 1 | | | 2 | 8 | 200,0 | 300,0 | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Pseudanabaenaceae | *Pseudanabaena minima* | | | 1,3 | 2,5 | | | 1,5 | 4 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Pseudanabaenaceae | *Pseudanabaena mucicola* | | | | | 1,3 | 2 | 1,3 | 4 | 10,0 | 50,0 | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Pseudanabaenaceae | *Pseudanabaena persicina* | | | 1,7 | 2 | | | 2 | 7 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Pseudanabaenaceae | *Pseudanabaena skujae* | | | 2,3 | 2,5 | | | 2,3 | 7,5 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Pseudanabaenaceae | *Pseudanabaena spelaea* | | | 0,8 | 1,2 | | | 0,8 | 2,4 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | insertae sedis | *Heteroleibleinia chaetomorphae* | | | | | 1,3 | 1,5 | | | | 27,0 | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | incertae sedis | *Heteroleibleinia kuetzingii* | 2 | 3,5 | 1,2 | 2 | | | 0,5 | 1 | 30,0 | 80,0 | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | incertae sedis | *Heteroleibleinia mesotricha* | | | | | 3 | 5 | 4 | 8 | | 1.000,0 | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | insertae sedis | *Schizothrix fragilis* | | 20 | 1,4 | 2,5 | | | 1 | 2 | | 1.000,0 | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | insertae sedis | *Schizothrix porphyromelana* | | | | | 3 | 4 | 2 | | | | [41][45] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | insertae sedis | *Schizothrix tenius* | 2 | 4 | 0,8 | 1,5 | | | | | | 3.000,0 | [41][45] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Leptolyngbyaceae | *Leibleinia epiphytica* | 1,5 | 2 | | | 1 | 1,5 | 1 | 2 | | | [41][45][55] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Leptolyngbyaceae | *Leptolyngbya bigranulata* | 0,8 | 1 | | | 0,5 | 0,9 | 9 | 13 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Leptolyngbyaceae | *Leptolyngbya granulifera* | | | | | 0,8 | 1,5 | 2,5 | 8,5 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Leptolyngbyaceae | *Leptolyngbya lagerheimii* | 2 | 2,5 | | | 1,5 | 2,5 | 2 | 3 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Leptolyngbyaceae | *Leptolyngbya laminosa* | | | | | 0,8 | 1,8 | 2 | 6,5 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Leptolyngbyaceae | *Leptolyngbya mucosa* | 3,2 | 3,8 | 2,5 | 3 | | | 5 | 10 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Leptolyngbyaceae | *Leptolyngbya nostocorum* | | | | | 1,1 | 2 | 1,5 | 25 | | | [41][51] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Leptolyngbyaceae | *Leptolyngbya perelegans* | 1,5 | 3 | 1 | 1,6 | | | 2 | 8 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Leptolyngbyaceae | *Leptolyngbya polysiphoniae* | 3 | 4 | 2 | 2,5 | | | 0,5 | 1,7 | | 200,0 | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Leptolyngbyaceae | *Leptolyngbya purpurascens* | | | 1,5 | 2,5 | | | 2 | 4,5 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Leptolyngbyaceae | *Leptolyngbya valderiana* | | 3 | 1,8 | 2,5 | | | 2,5 | 7,5 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Leptolyngbyaceae | *Planktolyngbya bipunctata* | 1,5 | 2 | | | 1 | 1,5 | 3,5 | 5,5 | | | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Leptolyngbyaceae | *Planktolyngbya limnetica* | 1 | 2 | | | 0,5 | 1,8 | 1 | 5 | 100,0 | 600,0 | [41][43] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Leptolyngbyaceae | *Tapinothrix janthina* | | | 1,5 | 2,3 | | | 1,5 | 2,3 | | 500,0 | [41][75] |
| CYANOBACTERIA | Cyanophyceae | Synechococcales | Leptolyngbyaceae | *Tapinothrix varians* | | | 2,2 | 2,5 | | | 1,1 | 1,3 | | 3.000,0 | [41][75] |

# Appendix II - Supplementary Table 1. *Cont.*

| kingdom | phylum | class | order | fam | spp | fil_width_min | fil_width_max | cell_width_min | cell_width_max | fil_length_min | fil_length_max | cell_length_min | cell_length_max | ref |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CHROMALVEOLATA | OCHROPHYTA | Phaeophyceae | Laminariales | Chordaceae | *Chorda asiatica* | 1500 | 3000 | | | 1000000 | 2000000 | | | [76] |
| CHROMALVEOLATA | OCHROPHYTA | Phaeophyceae | Laminariales | Chordaceae | *C. filum* | 5000 | 5000 | | | | 6000000 | | | [77] |
| CHROMALVEOLATA | OCHROPHYTA | Phaeophyceae | Laminariales | Chordaceae | *C. kikonaiensis* | 2500 | 2500 | | | 400000 | 500000 | | | [76] |
| CHROMALVEOLATA | OCHROPHYTA | Phaeophyceae | Laminariales | Chordaceae | *C. rigida* | 3500 | 3500 | | | 300000 | 500000 | | | [78] |
| CHROMALVEOLATA | OCHROPHYTA | Phaeophyceae | Laminariales | Pseudochordaceae | *Pseudochorda gracilis* | 1400 | 1400 | | | | 800000 | | | [79] |
| CHROMALVEOLATA | OCHROPHYTA | Phaeophyceae | Laminariales | Pseudochordaceae | *Pseudochorda nagaii* | 1500 | 1500 | | | | 600000 | | | [152] |
| CHROMALVEOLATA | OCHROPHYTA | Phaeophyceae | Stschapoviales | Stschapoviaceae | *Stschapovia flagellaris* | 400 | 1000 | | | | 2000000 | | | [80][41] |
| CHROMALVEOLATA | OCHROPHYTA | Phaeophyceae | Ectocarpales | Scytosiphonaceae | *Melanosiphon intestinalis* | 200 | 2000 | | | 20000 | 170000 | | | [81] |
| CHROMALVEOLATA | OCHROPHYTA | Phaeophyceae | Ectocarpales | Scytosiphonaceae | *Myelophycus cavus* | 1000 | 1500 | | | 50000 | 150000 | | | [82] |
| CHROMALVEOLATA | OCHROPHYTA | Phaeophyceae | Ectocarpales | Scytosiphonaceae | *Myelophycus simplex* | 4000 | 4000 | | | | 300000 | | | [82] |
| CHROMALVEOLATA | OCHROPHYTA | Phaeophyceae | Ectocarpales | Scytosiphonaceae | *Scytosiphon lomentaria* | 2300 | 2300 | | | | 330000 | | | [83] |
| CHROMALVEOLATA | OCHROPHYTA | Xanthophyceae | Tribonematales | Tribonemataceae | *Bumilleria* sp. 1 | | | 5 | 5.6 | | | 4 | 6.4 | [42] |
| CHROMALVEOLATA | OCHROPHYTA | Xanthophyceae | Tribonematales | Tribonemataceae | *Tribonema affine* | | | 4.6 | 6.5 | | | | | [84] |
| CHROMALVEOLATA | OCHROPHYTA | Xanthophyceae | Tribonematales | Tribonemataceae | *Tribonema delicatissimum* | | | 15 | 30 | | | 15 | 30 | [42] |
| CHROMALVEOLATA | OCHROPHYTA | Xanthophyceae | Tribonematales | Tribonemataceae | *Tribonema elegans* | | | 1,9 | 3,7 | | | | | [84] |
| CHROMALVEOLATA | OCHROPHYTA | Xanthophyceae | Tribonematales | Tribonemataceae | *Tribonema intermixtum* | | | 8,4 | 11,2 | | | | | [84] |
| CHROMALVEOLATA | OCHROPHYTA | Xanthophyceae | Tribonematales | Tribonemataceae | *Tribonema microchloron* | | | 2,8 | 3,7 | | | | | [84] |
| CHROMALVEOLATA | OCHROPHYTA | Xanthophyceae | Tribonematales | Tribonemataceae | *Tribonema minus* | | | 4,6 | 6,5 | | | | | [84] |
| CHROMALVEOLATA | OCHROPHYTA | Xanthophyceae | Tribonematales | Tribonemataceae | *Tribonema monochloron* | | | 2 | 3 | | | 18 | | [42] |
| CHROMALVEOLATA | OCHROPHYTA | Xanthophyceae | Tribonematales | Tribonemataceae | *Tribonema regulare* | | | 5,6 | 7,4 | | | | | [84] |
| CHROMALVEOLATA | OCHROPHYTA | Xanthophyceae | Tribonematales | Tribonemataceae | *Tribonema utriculosum* | | | 12,1 | 25 | | | | | [84] |
| CHROMALVEOLATA | OCHROPHYTA | Xanthophyceae | Tribonematales | Tribonemataceae | *Tribonema viride* | | | 10,2 | 13,1 | | | | | [84] |
| CHROMALVEOLATA | OCHROPHYTA | Xanthophyceae | Tribonematales | Tribonemataceae | *Tribonema viride* | | | 8 | 10 | | | | | [85] |
| CHROMALVEOLATA | OCHROPHYTA | Xanthophyceae | Tribonematales | Tribonemataceae | *Tribonema vulgare* | | | 7,4 | 9,3 | | | | | [84] |
| CHROMALVEOLATA | OCHROPHYTA | Xanthophyceae | Tribonematales | Tribonemataceae | *Xanthonema* | | | 3,5 | 10 | | | | | [86] |
| CHROMALVEOLATA | OCHROPHYTA | Xanthophyceae | Tribonematales | Tribonemataceae | *Xanthonema debile* | | | 6 | 8 | | | | | [86] |
| CHROMALVEOLATA | OCHROPHYTA | Xanthophyceae | Tribonematales | Tribonemataceae | *Xanthonema hormidioides* | | | 3,6 | 4,6 | | | | | [84] |
| CHROMALVEOLATA | OCHROPHYTA | Xanthophyceae | Tribonematales | Tribonemataceae | *Xanthonema montanum* | | | 0 | 5 | | | | | [86] |
| CHROMALVEOLATA | OCHROPHYTA | Xanthophyceae | Tribonematales | Tribonemataceae | *Xanthonema solidum* | | | 4 | 7,5 | | | | | [86] |
| CHROMALVEOLATA | OCHROPHYTA | Xanthophyceae | Tribonematales | Tribonemataceae | *Xanthonema sessile* | | | 4 | 5,5 | | | | | [86] |
| CHROMALVEOLATA | OCHROPHYTA | Xanthophyceae | Tribonematales | Tribonemataceae | *Xanthonema sessile* | | | 4 | 5 | | | | | [86] |
| CHROMALVEOLATA | OCHROPHYTA | Xanthophyceae | Tribonematales | Tribonemataceae | *Xanthonema exile* | | | 3.5 | 4.5 | | | 6 | 13 | [42] |
| ARCHAEPLASTIDA | RHODOPHYTA | Stylonematophyceae | Stylonematales | Stylonemataceae | *Purpureofilum apyrenoidigerum* | 10 | 25 | 10 | 14 | | 1000 | 6 | 12 | [87] |
| ARCHAEPLASTIDA | RHODOPHYTA | Compsopogonophyceae | Erythropeltales | Erythrotrichiaceae | *Erythrotrichia biseriata* | 10 | 27 | | | | 1000 | | | [88] |
| ARCHAEPLASTIDA | RHODOPHYTA | Compsopogonophyceae | Erythropeltales | Erythrotrichiaceae | *Erythrotrichia carnea* | 12 | 33,5 | 12 | 27 | 500 | 2000 | 14 | 30 | [88][89] |
| ARCHAEPLASTIDA | RHODOPHYTA | Compsopogonophyceae | Erythropeltales | Erythrotrichiaceae | *Erythrotrichia carnea f. tenuis* | 9 | 12 | 9 | 12 | | 1000 | 9 | 20 | [90] |
| ARCHAEPLASTIDA | RHODOPHYTA | Compsopogonophyceae | Erythropeltales | Erythrotrichiaceae | *Erythrotrichia tetraseriata* | 12 | 40 | | | 1000 | 4000 | | | [90] |
| ARCHAEPLASTIDA | RHODOPHYTA | Compsopogonophyceae | Erythropeltales | Erythrotrichiaceae | *Porphyrostromium japonicum* | 7.9 | 250 | 7.9 | 10.7 | | 5000 | 7.3 | 20 | [91] |
| ARCHAEPLASTIDA | RHODOPHYTA | Bangiophyceae | Bangiales | Bangiaceae | *Bangia* | 15 | 360 | | | | | | | [92][93] |
| ARCHAEPLASTIDA | RHODOPHYTA | Bangiophyceae | Bangiales | Bangiaceae | *Bangia atropurpurea* | 15 | 125 | 4 | 39 | 20000 | 100000 | 8 | 20 | [94][95][96] |
| ARCHAEPLASTIDA | RHODOPHYTA | Bangiophyceae | Bangiales | Bangiaceae | *Bangia atropurpurea* subsp. *Breviseqmenta* | 16 | 75 | | | 10000 | 30000 | | | [97] |
| ARCHAEPLASTIDA | RHODOPHYTA | Bangiophyceae | Bangiales | Bangiaceae | *"Bangia fuscopurpurea"* | 15 | 50 | | | | | | | [89] |
| ARCHAEPLASTIDA | RHODOPHYTA | Bangiophyceae | Bangiales | Bangiaceae | *Bangia vermicularis?* | 40 | 60 | | | | 30000 | | | [90] |
| ARCHAEPLASTIDA | RHODOPHYTA | Bangiophyceae | Bangiales | Bangiaceae | *Dione arcuata* | 47 | 80 | 47 | 60 | | 15000 | | | [98] |
| ARCHAEPLASTIDA | RHODOPHYTA | Bangiophyceae | Bangiales | Bangiaceae | *Minerva aenigmata* | 13 | 77 | 17 | 40 | 15000 | 100000 | | | [98] |
| ARCHAEPLASTIDA | RHODOPHYTA | Bangiophyceae | Bangiales | Bangiaceae | *Pseudobangia kaycoleia* | 29.4 | 83.3 | 29.4 | 49 | | 10000 | | | [99] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Cladophorales | Cladophoraceae | *Chaetomorpha aerea* | | | 87,5 | 350 | | 150000 | 70 | 270 | [100] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Cladophorales | Cladophoraceae | *Chaetomorpha antennina* | | | 150 | 250 | | | 300 | 900 | [101] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Cladophorales | Cladophoraceae | *Chaetomorpha billardierii* | | | 220 | 350 | | | | | [97] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Cladophorales | Cladophoraceae | *Chaetomorpha brachygona* | | | 50 | 187 | | | 50 | 242,5 | [100] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Cladophorales | Cladophoraceae | *Chaetomorpha clavata* | | | 320 | 680 | | 20000 | 210 | 840 | [100] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Cladophorales | Cladophoraceae | *Chaetomorpha collformis* | | | **1500** | **5000** | **100000** | **400000** | | | [97] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Cladophorales | Cladophoraceae | *Chaetomorpha iica* | | | 105 | 130 | | | | | [97] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Cladophorales | Cladophoraceae | *Chaetomorpha liqustica* | | | 250 | 300 | | | 250 | 300 | [102] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Cladophorales | Cladophoraceae | *Chaetomorpha linum ("C. crassa")* | | | 200 | 750 | | | 170 | 630 | [100] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Cladophorales | Cladophoraceae | *Chaetomorpha melagonium* | | | 400 | 600 | 20000 | 50000 | | | [97] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Cladophorales | Cladophoraceae | *Chaetomorpha minima* | | | 20 | 42,5 | | 5000 | 25 | 75 | [100] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Cladophorales | Cladophoraceae | *Chaetomorpha nodosa* | | | 32,5 | 82,5 | | 120000 | 30 | 95 | [100] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Cladophorales | Cladophoraceae | *Chaetomorpha philippinensi* | | | 9 | 14 | | 300 | 15 | 35 | [103] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Cladophorales | Cladophoraceae | *Chaetomorpha valida* | | | 200 | 475 | 150 | 1000 | | | [104][105][106][107] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Cladophorales | Cladophoraceae | *Chaetomorpha vieillardii* | | | 486 | 534 | | | 730 | 890 | [108] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Cladophorales | Cladophoraceae | *Rhizoclonium hieroglyphicum* | | | 10 | 37 | | | 2x | 6x | [42] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Cladophorales | Cladophoraceae | *Rhizoclonium riparium* | | | 20 | 32 | | | | | [109] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Cladophorales | Okellyaceae | *Okellya curvata* | | | 3.5 | 10 | 100 | 200 | | 21 | [110] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Ulotrichales | Kraftionemaceae | *Kraftionema allantoideum* | | | 6 | 8 | | 1500 | 10 | 18 | [111] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Ulotrichales | Ulotrichaceae | *Gloeotilopsis sterilis* | | | 4.5 | 5.7 | | 402 | 6.1 | 13.4 | [112] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Ulotrichales | Ulotrichaceae | *Hormidiopsis crenulata* | | | 9 | 25 | | | 0,5 | 2x | [42] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Ulotrichales | Ulotrichaceae | *Pearsoniella variabilis* | | | 22 | 40 | | | 20 | 90 | [113] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Ulotrichales | Ulotrichaceae | *Ulothrix aequalis* | | | 13 | 15 | | | 18 | 30 | [114] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Ulotrichales | Ulotrichaceae | *Ulothrix albicans* | | | 7.7 | 12.6 | | | 1/2x | 2x | [115] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Chaetophorales | Uronemataceae | *Ulothrix qigas* | | | 10 | 21,25 | | | 8,2 | 22 | [116][117] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Ulotrichales | Ulotrichaceae | *Ulothrix implexa* | | | 9,8 | 15,4 | | | 1/3x | 1x | [118] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Ulotrichales | Ulotrichaceae | *Ulothrix subflaccida* | | | 9 | 11 | | | | | [97] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Ulotrichales | Ulotrichaceae | *Ulothrix tenerrima* | | | 7 | 10 | | | 10 | 15 | [119] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Ulotrichales | Ulotrichaceae | *Ulothrix tenuissima* | | | 15 | 20 | | | | | [102] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Ulotrichales | Ulotrichaceae | *Ulothrix zonata* | | | 20 | 40 | | | 20 | 60 | [102] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Ulotrichales | Ulotrichaceae | *Urospora bangioides* | | | 14 | 180 | | 80000 | 9 | 220 | [120] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Ulotrichales | Ulotrichaceae | *Urospora neglecta* | | | | | | 70000 | | | [120] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Ulotrichales | Ulotrichaceae | *Urospora penicilliformis* | | | 9 | 90 | 50000 | 60000 | | | [120] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Ulvophyceae | Ulotrichales | Ulotrichaceae | *Urospora wormskioldii* | | | 18 | 1500 | | 110000 | 9 | 450 | [120] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Chaetophorales | Schizomeridaceae | *Schizomeris leibleinii* | 20 | 54 | 10 | 30 | | | 10 | 55 | [119][42] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Chaetophorales | Uronemataceae | *Uronema africanum* | | | 4 | 5 | | | 12 | 32 | [119] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Chaetophorales | Uronemataceae | *Uronema confervicola* | | | 4 | 7 | | | 9 | 18 | [42] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Chaetophorales | Uronemataceae | *Uronema elongatum* | | | 4 | 6 | | | 13 | 45 | [119] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Chaetophorales | Uronemataceae | *Uronema subelongatum* | | | 5 | 7 | | | 50 | 85 | [119] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Chaetophorales | Uronemataceae | *Uronema trentonense* | | | 4 | 8 | | | 12 | 40 | [121] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium acuminatum* | | | 10 | 14 | | | 18 | 42 | [122] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium anomalum* | | | 35 | 45 | | | 85 | 120 | [102] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium borisianum* | | | 15 | 17 | | | 57 | 66,5 | [116] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium braunii* | | | 19 | 24 | | | 48 | 95 | [122] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium boscii* | | | 10 | 12 | | | 90 | 110 | [123] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium capillare* | | | 33 | 60 | | | 31 | 55 | [122][124] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium capilliforme* | | | 25 | 38 | | | 1,5x | 3x | [42] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium crassum* | | | 24 | 50 | | | 2x | 8x | [42] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium crispum* | | | 9 | 21 | | | 28 | 70 | [122] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium curtum* | | | 12 | 22 | | | 2x | 5x | [42] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium curvum* | | | 5 | 10 | | | 1,5x | 4x | [42] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium cyathigerum* | | | 21 | 42 | | | 50 | 86 | [122] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium cymatosporum* | | | 7 | 8 | | | 34 | 50 | [122] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium didymum* | | | 19 | 28 | | | 21 | 49 | [122] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium echinospermum* | | | 18 | 30 | | | 2x | 5x | [42] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium gracilius* | | | 20 | 29 | | | 29 | 76 | [122] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium grae* | | | 24 | 34 | | | 130 | 200 | [123] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium hiustanense* | | | 15 | 25 | | | | | [102] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium itzigsohnii* | | | 5 | 11 | | | 2x | 6x | [42] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium laeve* | | | 9 | 10 | | | 25 | 29 | [125] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium lagerheimiforme* | | | 13 | 13,5 | | | 38 | 57,5 | [116] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium mexicanum* | | | 34 | 40 | | | 60 | 100 | [102] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium pakistanense* | | | 9 | 15 | | | 28 | 32 | [126] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium peipingens* | | | 30 | 32 | | | 110 | 150 | [125] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium pisanum* | | | 13 | 16 | | | 40 | 55 | [125] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium plagiostomum* | | | | 20 | | | 40 | 60 | [125] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium pringsheimii* | | | 11 | 21 | | | 21 | 50 | [122] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium praelongum* | | | 7 | 11 | | | 50 | 150 | [123] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium princeps* | | | 33 | 45 | | | 1,25x | 3x | [42] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium pringsheimii* | | | 15 | 20 | | | 40 | 80 | [102] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium cf. pseudomitratum* | | | 11 | 14 | | | 28 | 49 | [122] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium punctatostriatum* | | | 13 | 22 | | | 4x | 7x | [42] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium sp.aff. pyrulum* | | | 15 | 21 | | | 23 | 48 | [122] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogoniwn reinschii* | | | 6 | 8,5 | | | 12 | 15 | [127] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium richterianum* | | | 12 | 22 | | | | 130 | [42] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium ruqulosum* | | | 4 | 8 | | | | 35 | [42] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium sangirica* | | | 12 | 13 | | | 19 | 38 | [128] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium sociale* | | | 13 | 14 | | | 43 | 58 | [116] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium subdissimile* | | | 8 | 15 | | | 21 | 55 | [116][122] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium subplagiostomum* | | | 9 | 12 | | | 30 | 45 | [116] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium stellatum* | | | 15 | 35 | | | 2x | 8x | [42] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium tapeinosporum* | | | 5 | 8 | | | 22 | 27 | [125] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium uulatum* | | | | 18,7 | | | | 66 | [125] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium vaucherii* | | | 20 | 28 | | | 1,5x | 4x | [42] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Oedogoniales | Oedogoniaceae | *Oedogonium westii* | | | 17 | 35 | | | 3x | 6x | [42] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Sphaeropleales | Sphaeropleaceae | *Sphaeroplea annulina* | | | 27 | 72 | | | | 20x | [42] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Sphaeropleales | Sphaeropleaceae | *Sphaeroplea fragilis* | | | 16 | 65 | | | 7 | 45 | [129] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Sphaeropleales | Sphaeropleaceae | *Sphaeroplea robusta* | | | 56 | 72 | | | 400 | 1000 | [130] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Sphaeropleales | Sphaeropleaceae | *Sphaeroplea tenuis* | | | 10 | 12 | | | | | [131] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Sphaeropleales | Microsporaceae | *Microspora abbreviata* | | | 5 | 7 | | | 25 | 37 | [102] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Sphaeropleales | Microsporaceae | *Microspora amoena* | | | 21.5 | 27 | | | 17 | 38 | [132][114] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Sphaeropleales | Microsporaceae | *Microspora floccosa* | | | 12 | 27 | | | 25 | 37 | [114][102] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Sphaeropleales | Microsporaceae | *Microspora loefgrenii* | | | 14 | 17 | | | 10 | 20 | [119] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Sphaeropleales | Microsporaceae | *Microspora manifesta* | | | 15 | 17 | | | 17 | 39 | [132] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Sphaeropleales | Microsporaceae | *Microspora membranacea* | | | 29 | 32,5 | | | 78 | 177 | [117] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Sphaeropleales | Microsporaceae | *Microspora pachyderma* | | 12.5 | 9 | 10 | | | 10 | 22 | [119] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Sphaeropleales | Microsporaceae | *Microspora quadrata* | | | 6 | 8 | | | 4 | 15 | [132][116][119] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Sphaeropleales | Microsporaceae | *Microspora rotuata* | | | 7 | 10 | | | 6 | 10 | [132] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Sphaeropleales | Microsporaceae | *Microspora stagnorum* | | | 7 | 11 | | | 8 | 25 | [132][114] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Sphaeropleales | Microsporaceae | *Microspora tumidula* | | | 7.5 | 9 | | | 10 | 18,5 | [127] |

# Appendix II - Supplementary Table 1. *Cont.*

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Sphaeropleales | Microsporaceae | *Microspora willeana* | | | 10 | 15 | | | 10 | 20 | [102] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Sphaeropleales | Microsporaceae | *Microspora wittrockii* | | | 14 | 17 | | | 11 | 21 | [132] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Sphaeropleales | Microsporaceae | *Microspora* sp.A | | | 8 | 11 | | | 6 | 20 | [132] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Chlorophyceae | Sphaeropleales | Cylindrocapsaceae | *Cylindrocapsa geminella* | | | 13 | 28,7 | | | 14 | 55 | [133][119][117] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Trebouxiophyceae | | | *Koliellopsis inuata* | | | 2,7 | 3,8 | | | 3x | 8x | [134] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Trebouxiophyceae | Prasiolales | Prasiolaceae | *Rosenvingiella polyrrhiza* | 12 | 40 | | | | | | | [97] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Trebouxiophyceae | Prasiolales | Prasiolaceae | *Rosenvingiella tasmanica* | 20 | 26 | | | | | 1/3x | 1/6x | [135] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Trebouxiophyceae | Chlorellales | Chlorellaceae | *Geminella ellipsoidea* | 10 | 15 | 4.2 | 7.3 | | | 2.8 | 5.5 | [42] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Trebouxiophyceae | Chlorellales | Chlorellaceae | *Geminella interrupta* | 15 | 30 | 6 | 9 | | | 1.5x | 2x | [42] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Trebouxiophyceae | Chlorellales | Chlorellaceae | *Geminella minor* | 6 | 15 | 2 | 8 | | | 1x | 3x | [42] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Trebouxiophyceae | Chlorellales | Chlorellaceae | *Geminella planctonica* | 20 | 50 | 4 | 7 | | 5000 | 5 | 12 | [136] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Trebouxiophyceae | Chlorellales | Chlorellaceae | *Geminella ordinata* | 15 | 20 | 5 | 9 | | | | 1,5x | [42] |
| ARCHAEPLASTIDA | CHLOROPHYTA | Trebouxiophyceae | Chlorellales | Chlorellaceae | *Gloeotila subconstricta* | | | 7 | 10 | | | 40 | 45 | [119] |
| ARCHAEPLASTIDA | | Klebsormidiophyceae | Klebsormidiales | Klebsormidiaceae | *Klebsormidium acidophilum* | | | 6 | 8 | | | 8 | 15 | [137] |
| ARCHAEPLASTIDA | | Klebsormidiophyceae | Klebsormidiales | Klebsormidiaceae | *Klebsormidium dissectum* | | | 8 | 9 | | | 12 | 22 | [137] |
| ARCHAEPLASTIDA | | Klebsormidiophyceae | Klebsormidiales | Klebsormidiaceae | *Klebsormidium elegans* | | | 11 | 15 | | | 10 | 22 | [137] |
| ARCHAEPLASTIDA | | Klebsormidiophyceae | Klebsormidiales | Klebsormidiaceae | *Klebsormidium flaccidum* | | | 6 | 8 | | | 1x | 1.4x | [138] |
| ARCHAEPLASTIDA | | Klebsormidiophyceae | Klebsormidiales | Klebsormidiaceae | *Klebsormidium fluitans* | | | 7 | 8.5 | | | 1x | 1.5x | [138] |
| ARCHAEPLASTIDA | | Klebsormidiophyceae | Klebsormidiales | Klebsormidiaceae | *Klebsormidium mucosum* | | | 15 | 20 | | | | | [138] |
| ARCHAEPLASTIDA | | Klebsormidiophyceae | Klebsormidiales | Klebsormidiaceae | *Klebsormidium nitens* | | | 6.5 | 6.5 | | | 1x | 1.5x | [138] |
| ARCHAEPLASTIDA | | Klebsormidiophyceae | Klebsormidiales | Klebsormidiaceae | *Klebsormidium rivulare* | | | 5 | 11 | | | 1x | 3x | [138] |
| ARCHAEPLASTIDA | | Klebsormidiophyceae | Klebsormidiales | Klebsormidiaceae | *Klebsormidium* sp. | | | | 6.5 | | 984 | 12.3 | | [139] |
| ARCHAEPLASTIDA | | Klebsormidiophyceae | Klebsormidiales | Klebsormidiaceae | *Klebsormidium* sp. | | | | 4.75 | | 4920 | 8.72 | | [139] |
| ARCHAEPLASTIDA | | Klebsormidiophyceae | Klebsormidiales | Klebsormidiaceae | *Klebsormidium* sp. | | | | 5.25 | | 3150 | 9 | | [139] |
| ARCHAEPLASTIDA | | Klebsormidiophyceae | Klebsormidiales | Klebsormidiaceae | *Klebsormidium* sp. | | | | 5.5 | | 625 | 12.5 | | [139] |
| ARCHAEPLASTIDA | | Klebsormidiophyceae | Klebsormidiales | Klebsormidiaceae | *Klebsormidium* sp. | | | | 5.5 | | 665 | 9.5 | | [139] |
| ARCHAEPLASTIDA | | Klebsormidiophyceae | Klebsormidiales | Klebsormidiaceae | *Klebsormidium* sp. | | | | 8 | | 11900 | 11.9 | | [139] |
| ARCHAEPLASTIDA | | Klebsormidiophyceae | Klebsormidiales | Klebsormidiaceae | *Klebsormidium subtile* | | | 4 | 7 | | | 1x | 5x | [42] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia abnormis* | | | | | | | | | [127] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia acadiana* | | | 43 | 53 | | | | | [140] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia angolensis* | | | 25 | 29 | | | | | [140] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia calcarea* | | | 8 | 13 | | | 40 | 250 | [42] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia capucina* | | | 18 | 23 | | | | | [140] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia disjuncta* | | | 12.5 | 14 | | | | | [140] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia guanahacabibensis* | | | 26 | 35,5 | | | | | [140] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia hupehensis* | | | 27 | 30 | | | | | [140] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia laevis* | | | 25 | 31 | | | 80 | 100 | [42] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia laetevirens* | | | 23 | 30 | | | | | [140] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia longiarticulata* | | | 11 | 16 | | | 90 | 180 | [140] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia mesocarpiana* | | | 16 | 17,5 | | | | | [141] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia nummuloides* | | | 10 | 12 | | | | | [140] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia oblongata* | | | 19 | 22 | | | | | [140] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia oedogonioides* | | | 16 | 18 | | | | | [140] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia opelousasensis* | | | 25 | 30 | | | | | [140] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia producta* | | | 7 | 8 | | | | | [140] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia pseudo-opelousasensis* | | | 27 | 29 | | | | | [140] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia punctata* | | | 8 | 12 | | | | | [140] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia robusta* | | | 25 | 33 | | | | 220 | [42] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia sphaerocarpa* | | | 18 | 20 | | | | | [140] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia subpunctata* | | | 5 | 6,5 | | | | | [140] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia transeauii* | | | 14 | 17 | | | | 10x | [140] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia trapaeziformis* | | | 4,5 | 5,5 | | | 41 | 68 | [140] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia tumidula* | | | 11 | 14 | | | | | [140] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia varians* | | | 25 | 27 | | | | | [140] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia viscosa* | | | 14 | 18 | | | | | [140] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Mougeotia viridis* | | | 6 | 9 | | | | | [140] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra australica* | | | 27 | 30 | | | 60 | 133 | [42] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra bellis* | | | 65 | 80 | | | 90 | 350 | [42] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra borgeana* | | | 30 | 35 | | | 50 | 200 | [142] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra brunnea* | | | 50 | 70 | | | 120 | 260 | [102] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra californica* | | | 51 | 60 | | | 120 | 400 | [42] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra catenaeformis* | | | 24 | 33 | | | 60 | 200 | [42] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra chungkingensis* | | | 24.9 | 25,6 | | | 73,5 | 224 | [143] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra colligata* | | | 29 | 40 | | | 90 | 280 | [144][42] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra columbiana* | | | 46 | 58 | | | | | [145] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra daedalea* | | | 35 | 40 | | | 150 | 220 | [102] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra decimina* | | | 28 | 36 | | | 118 | 633 | [143] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra distenta* | | | 48 | 54 | | | | | [145] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra dubia* | | | 51.2 | 59.5 | | | 156.8 | 275.2 | [143] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra longata* | | | 21 | 38 | | | 50 | 320 | [145][42] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra emilianensis* | | | 50 | 53 | | | 80 | 90 | [146] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra fennica* | | | 15,5 | 18 | | | 72 | 100 | [127] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra fluviatilis* | | | 30 | 56 | | | 80 | 240 | [145][42] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra hassallii* | | | 24 | 35 | | | | | [145] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra hyalina* | | | 45 | 65 | | | 80 | 240 | [102] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra inflata* | | | 17 | 19 | | | 85 | 140 | [116] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra juliana* | | | 52 | 64 | | | 56 | 120 | [42] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra koreana* | | | 51.2 | 56.9 | | | 288 | 819 | [143] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra jaoensis* | | | 50 | 55 | | | 80 | 200 | [146] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra luzalis* | | | 83.2 | 89.6 | | | 102.4 | 134.4 | [143] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra kuusamoensis* | | | 15 | 16 | | | 90 | 1600 | [42] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra lutetiana* | | | 35 | 41 | | | 70 | 140 | [42] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra majuscula* | | | 50 | 100 | | | 120 | 250 | [145][42] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra maravillosa* | | | 20 | 30 | | | 100 | 250 | [102] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra maxima* | | | 120 | 150 | | | 90 | 280 | [42] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra minutifossa* | | | 13 | 16 | | | 65 | 95 | [127] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra multiconiugata* | | | 23 | 32 | | | | | [147] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra neglecta* | | | 55 | 68 | | | | | [145] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra notabilis* | | | 33 | 35 | | | 100 | 309 | [42] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra pascheriana* | | | 17 | 20 | | | 135 | 145 | [146] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra parvula* | | | 20 | 24 | | | 60 | 170 | [42] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra plena* | | | 35 | 45 | | | 55 | 85 | [142] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra porticalis* | | | 39 | 55 | | | | | [145] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra protecta* | | | 29 | 42 | | | 130 | 405 | [42] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra rhizobrachalis* | | | 40 | 85 | | | 115 | 200 | [147] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra scrobiculata* | | | 32 | 38 | | | 55 | 100 | [42] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra semiornata* | | | 25 | 46 | | | | | [145] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra setiformis* | | | 90 | 120 | | | 120 | 140 | [102] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra silesiaca* | | | 43 | 52 | | | | | [144] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra spreeiana* | | | 18 | 23 | | | 140 | 600 | [42] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra subcolligata* | | | 37 | 41 | | | | | [144] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra teodorescui* | | | 23 | 30 | | | 50 | 160 | [145][42] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra varians* | | | 35 | 40 | | | 40 | 203 | [42] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra velata* | | | 29 | 44 | | | | | [145] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra weberi* | | | 20 | 25 | | | 90 | 550 | [146] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Spirogyra vuin* | | | 45 | 55 | | | | | [144] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Zygnema aplanosporum* | | | 24.1 | 33.2 | | | 12.5 | 124 | [42] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Zygnema californicum* | | | 23 | 29 | | | 32 | 89 | [148] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Zygnema carinthiacum* | | | 26 | 28 | | | | | [148] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Zygnema collinsianum* | | | 18 | 25 | | | 40 | 60 | [102] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Zygnema cruciatum* | | | 32 | 39 | | | 35 | 50 | [149] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Zygnema gigantеum* | | | 36 | 43 | | | | | [148] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Zygnema insignis* | | | 25 | 29 | | | 46 | 52,5 | [127] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Zygnema irregulare* | | | 36 | 40 | | | | | [148] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Zygnema leiospermum* | | | 22 | 30 | | | 27 | 100 | [150] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Zygnema oudhense* | | | 20 | 30 | | | 50 | 72 | [102] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Zygnema ovoidanum* | | | 10 | 12,5 | | | 40 | 65 | [127] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Zygnema sterile* | | | 45 | 55 | | | | | [148] |
| ARCHAEPLASTIDA | | Zygnematophyceae | Zygnematales | Zygnemataceae | *Zygnema wabashensis* | | | 33 | 55 | | | 125 | 240 | [102] |

# Appendix II - Supplementary Table 1. *Cont.*

| Nº | Reference |
|---|---|
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# Appendix II - Supplementary Table 1. *Cont.*


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Appendix III - Supplementary Table 1. Infrared absorption bands of the selected samples (clay fraction)

| Sample code | Outcrop | Dep Seq | Material | Si–O bend | | | | |
|---|---|---|---|---|---|---|---|---|
| IB7 | AF222 | DS1 | Fine silicilasts (mud and silt) | 418sh | | | **429** | |
| IB1 | AF151 | DS1 | Fine silicilasts | 416sh | | 425sh | **430** | |
| IB2 | AF153 | DS1 | Fine silicilasts | 416sh | | 425sh | **428** | |
| IB5 | AF236 | DS1 (Arumberia level) | Fossiliferous beds (Arumberia) | 416sh | 423sh | | **430** | |
| IB6 | AF236 | DS1 | Fine silicilasts | | | **426** | | |
| IB8 | M9 | DS1 | Fine silicilasts | | | | **428** | |
| IB9 | M11 | DS1 | Fine silicilasts | | 421sh | **426** | | 436 |
| IB10 | M12 | DS1 | Fine silicilasts | 417sh | 422sh | | **430** | |
| IB12 | AF103 | DS2 | Fine silicilasts | | | | **428** | |
| IB13 | AP1 | DS2 | Fine silicilasts | 415sh | 423sh | | **430** | 436sh |
| IB14 | AF19 | DS2 | Fine silicilasts | 416sh | | 426sh | **431** | 435sh |
| IB15 | AF9 | DS2 | Fine silicilasts | | 423sh | 426 | **431** | 436sh |
| A16 | A16 | DS2 | Fossiliferous beds | 416sh | | 426sh | **430** | 436sh |
| IB20 | AF14 | DS2-DS3 | Fine silicilasts | 415sh | | | **431** | 436sh |
| IB17 | AF57 | DS3 | Fine silicilasts | | 420sh | | **429** | |
| IB22 | AF80 | DS3 | Fine silicilasts | | | | **429** | |
| IB23 | B16 | DS4 (Similar to A16) | Fossiliferous beds | | 420sh | **426** | 431sh | |
| IB24 | AF172 | DS4 | Fine silicilasts | | | | | |
| IB3 | AF236 | DS1 | Silicified tuffite (chert) | | | **426** | | |
| IB4 | AF236 | DS1 | Silicified tuffite (chert) | **416** | | | | |
| IB29 | AFZ | DS5? | Vitric tuffite (chert) | | | **426** | | |
| IB11 | M12 | DS1 | Argillaceous tuff | | **423** | | | |
| 04 (MM) | A16 | DS2 | Fossil clays | | **429** | | | |
| 05 (CL) | A16 | DS2 | Coarse-grained volcaniclastic laminae | | **430** | | | |

Appendix III - Supplementary Table 1. *Cont.*

| | | Si–O–Si bend | | | | Si–O–Al | | | Alb | Feldspars | Si-O | Feldspars |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **470** | | | | 520sh | **531** | | | 649w | **695** | ~725? |
| | | **469** | 474sh | | | **520** | 529sh | | | 649 | **695** | ~724 |
| | 463sh | **469** | 474sh | | | **522** | 529sh | | | 648 | **695** | ~725? |
| | 463sh | **471** | 475sh | | **518** | | 531sh | | 589sh | 648 | **696** | ~724 |
| | | **469** | 475sh | | | **525** | | | 589sh | 649 | **695** | ~725 |
| | | **470** | | | | 520sh | | **532** | | 644 | **696** | ~725? |
| | 464sh | **470** | | | | **521** | 530sh | | 589sh | 649 | **695** | ~725 |
| | 462sh | **468** | 473sh | | | 523sh | 529sh | **533** | | 643 | **696** | |
| | | **469** | 474sh | | | **520** | 528sh | | 590sh | 649 | **696** | ~725 |
| 443sh | | **470** | | | 515sh | **523** | 528sh | 533sh | | 649 | **696** | ~725? |
| | | **470** | | | **518** | | 529sh | | | 648 | **696** | ~725? |
| 445 | | **470** | 474sh | | 516sh | | **527** | 533sh | | 646 | **695** | ~725 |
| | | **470** | | | | **525** | | | | | **696** | |
| | 457sh 463sh | **468** | **471** | | **518** | | | **535** | 589sh | **646** | **696** | 725 |
| | 468sh | **472** | | | | 522sh | **529** | 534sh | | | **695** | |
| | | **472** | | | | | **526** | | | | **696** | |
| | | **471** | | | | **521** | | | 589sh | ~643 | ~695 | ~725? |
| | | | | | | | | | | ~653 | **695** | |
| | 464sh | **470** | 474sh | | **515** | | | | 591sh | 647 | **695** | |
| | 464sh | **468** | **474** | 478 | **515** | | | 534sh | 591sh | 647 | **695** | |
| | 464sh | **468** | 472 | 480sh | **516** | | | | 591sh | 645 | **695** | |
| | | | 472 | | | **524** | | | | | | |
| | | **471** | ~475sh | | | | **528** | | | | **697** | |
| | | **471** | | | | | **526** | | | | **696** | |

Appendix III - Supplementary Table 1. *Cont.*

| Albite | Al–O–Si in plane | Qz | Qz | Al-O out-of-plane | | AlOHAl bend | | Si-O-Si stretching | Si-O-Si stretchin | | SiOap stretch |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 746 | ~761 | **779** | **797** | 830 | ~878 | **911** | | **1007** | **1028** | | 1079 |
| 746 | ~761 | **779** | **798** | 827 | ~878 | **912** | | 1012sh | **1028** | | **1086** |
| 746 | ~761 | **779** | **798** | 827 | ~878 | **911** | | 1012sh | **1027** | | **1085** |
| 746 | ~761 | **779** | **799** | 827 | ~878 | **915** | | 1012 | **1033** | 1062sh | **1090** |
| 746 | ~761 | **779** | **798** | 827 | ~878 | **912** | | 1012 | **1029** | 1062sh? | **1085** |
| | ~752 | **779** | **799** | 827 | ~878 | **912** | | **1008** | **1030** | | **1082** |
| 746 | ~761 | **779** | **799** | 827 | ~878 | **911** | | 1007 | **1029** | | **1085** |
| | ~752 | **779** | **799** | 827 | ~878 | **911** | | **1007** | **1031** | | **1084** |
| ~747 | ~760 | **779** | **798** | 828 | ~878 | **911** | ~935 | 1008 | **1029** | | **1087** |
| ~746 | ~760 | **779** | **798** | 828 | ~878 | **911** | ~935 | 1008 | **1029** | | 1081 |
| | ~760 | **779** | **799** | 828 | ~878 | **912** | | 1008 | **1029** | | **1087** |
| ~746 | 760 | **779** | **798** | 828 | ~878 | **912** | | 1008 | **1029** | | 1087sh |
| | ~755 | **779** | **799** | 825 | ~878 | **913** | | 1012 | **1032** | | **1084** |
| | | **779** | **799** | | ~878 | **913** | ~940 | **1010** | **1033** | ~1060 | **1082** |
| | ~755 | **~778** | **798** | 828 | ~878 | **912** | | ~1008 | **1030** | 1076 | |
| | | **779** | **797** | | | **912** | | 1011 | **1030** | | |
| ~746 | ~755 | **798** | **778** | 828 | ~878 | **912** | | ~1008 | **1030** | ~1060 | 1084 |
| | ~755 | **798** | **~778** | 828 | ~878 | **912** | | 1008 | **1030** | | **1082** |
| | | **779** | **799** | 828 | ~878 | **910** | | | **1034** | ~1061 | **1090** |
| | | **779** | **799** | 828 | ~878 | **912** | | | **1034** | ~1062 | **1087** |
| | | **779** | **799** | 828 | ~878 | **913** | | | **1034** | | **1090** |
| | ~750 | 779 | 800 | 827 | ~878 | **911** | | ~1012 | **1028** | | ~1080 |
| | ~754 | **779** | **800** | ~830 | ~874 | **913** | | ~1011 | **1032** | | **1085** |
| | ~754 | **779** | **799** | ~828 | ~878 | **913** | | ~1012 | **1033** | | **1083** |

Appendix III - Supplementary Table 1. *Cont.*

| SiOap stretch | Qz | Aliphatic compounds | | | OH-stretch | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1110sh | 1162 | 2855 | 2926 | 2963 | | 3599sh | **3620** | 3628sh? | | | **3698** |
| 1110sh | 1163 | 2855 | 2926 | | 3568 | 3599sh | **3620** | 3628sh | 3652? | 3669? | **3698** |
| 1110sh | 1163 | 2855 | 2926 | 2966 | | 3599sh | **3620** | 3628sh? | | | **3698** |
| | 1164 | 2855 | 2926 | | 3568 | | **3622** | 3628sh | 3652? | 3669? | **3700** |
| | 1163 | 2855 | 2926 | | 3568? | | **3620** | 3628sh | | | **3700** |
| 1112sh | 1163 | 2855 | 2926 | | | 3599sh | **3620** | | 3652 | 3669 | **3698** |
| 1112sh | 1164 | 2855 | 2926 | | | 3599sh | **3620** | 3628sh? | | | **3698** |
| 1112sh | 1164 | 2855 | 2926 | | | 3599sh | **3620** | | 3652 | 3669 | **3698** |
| | ~1164 | 2856w | 2926w | | 3568sh | 3599sh | **3620** | 3628sh | | | **3700** |
| ~1112 | ~1163 | 2856w | 2926w | | 3568sh | 3599sh | **3620** | 3628sh | ~3652 | ~3669 | **3700** |
| ~1112 | ~1164 | 2856w | 2926w | | 3568sh | 3599sh | **3620** | 3628sh | ~3652 | ~3669 | **3699** |
| ~1112 | ~1162 | 2856w | 2926w | | 3568sh | 3599sh | **3620** | 3628sh | ~3652 | ~3669 | **3700** |
| ~1112 | ~1164 | 2856 | 2926 | 2960 | 3568sh | | **3621** | 3628sh | ~3652 | ~3669 | **3701** |
| ~1112 | ~1163 | 2856 | 2928 | 2975 | 3568sh | 3599sh | **3620** | 3628sh | ~3652 | ~3670 | **3696** |
| ~1112 | ~1163 | 2856 | 2928 | 2975? | 3568sh | 3599sh | **3622** | 3628sh | ~3652 | ~3670 | **3701** |
| | ~1164 | 2856 | 2928 | | | 3599sh | **3622** | 3628sh | | ~3670 | **3701** |
| | ~1164 | 2856 | 2928 | | 3568sh | 3599sh | **3620** | 3628sh | ~3653 | ~3670 | **3700** |
| ~1112 | ~1165 | 2856 | 2928 | 2962 | 3568sh | 3599sh | **3620** | 3628sh | ~3654 | ~3670 | **3698** |
| | ~1165 | 2856 | 2926 | 2961 | | | **3622** | 3629sh | | | |
| | ~1164 | 2856 | 2928 | 2970 | 3568sh | | **3622** | 3629sh | | | |
| | ~1165 | 2856 | 2928 | | 3568sh | | **3622** | 3629sh | | | **3696** |
| | | 2856 | 2928 | 2961 | 3568sh | | **3620** | 3629sh | | | |
| ~1112 | 1164 | 2855 | 2927 | 2960 | | ~3604sh | **3623** | | ~3656 | | **3702** |
| ~1112 | 1164 | 2855 | 2927 | 2960 | | ~3604sh | **3622** | | ~3656 | | **3702** |

Appendix III - Supplementary Table 1. *Cont.*

| | | | | (v+δ)AlMgOH? | $AlFe^{3+}OH$? | Illite | | | $H_2O$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ~4088 | ~4181w | 4240w | ~4364 | | ~4466sh | | **4524** | 4621sh | **5216** | 6812sh | 7020sh |
| ~4088 | ~4190w | 4241w | ~4364 | | ~4466sh | ~4503sh | **4524** | 4621sh | **5221** | | 7020sh |
| ~4088 | ~4190w | 4241w | | 4449sh | | ~4503sh | **4522** | | **5222** | | |
| ~4083 | ~4190w | 4247w | | 4446 | | ~4503sh | **4528** | | **5227** | | |
| ~4088 | ~4190w | 4246w | | 4446 | | | **4522** | | **5221** | | |
| ~4088 | ~4190 | 4239w | | | ~4466sh | | **4526** | 4621sh | **5222** | | 7020sh |
| ~4088 | ~4190w | 4241w | | 4446 | | ~4503sh | **4522** | | **5214** | | 7020sh |
| ~4088 | ~4190 | 4240w | | | ~4466sh | | **4526** | 4621sh | **5220** | | 7020sh |
| ~4088 | ~4190 | ~4246 | | ~4442 | | | **4520** | | **5221** | | |
| ~4088 | ~4190 | ~4247 | | ~4442 | | | **4525** | | **5232** | | |
| ~4088 | ~4190 | ~4248 | | ~4442 | | | **4525** | | **5228** | | |
| ~4090 | ~4190 | ~4249 | | ~4442 | | | **4526** | | **5232** | | |
| ~4083 | ~4190 | ~4250 | | ~4442 | | ~4503sh | **4529** | | **5221** | | |
| ~4088 | ~4192 | 4240 | | | | | **4527** | ~4622 | **5222** | | ~7018sh |
| ~4088 | ~4190 | 4246 | | | | | **4527** | | **5228** | | |
| ~4088 | ~4190 | 4246 | | | | | **4527** | | **5228** | | |
| ~4083 | ~4192 | 4250 | | 4440 | | ~4506sh | **4523** | | **5225** | | |
| ~4088 | ~4190 | 4243 | | | | | **4526** | | **5222** | | ~7018sh |
| ~4090 | | 4249 | | ~4439 | | | **4528** | | **5229** | | |
| ~4090 | | 4251 | | ~4440 | | | **4532** | | **5229** | | |
| ~4090 | | 4247 | | ~4441 | | | **4529** | | **5213** | | |
| ~4083 | | 4249 | | ~4442 | | **4509** | | 4700 | **5229** | ~6830 | |
| ~4083 | 4189 | 4249 | | ~4442 | | | **4529** | | **5238** | ~6830 | |
| ~4083 | 4189 | 4247 | | ~4442 | | | **4529** | | **5224** | | |

Appendix III - Supplementary Table 1. *Cont.*

| 2v(OH) overtone | | |
|---|---|---|
| **7065** | ~7170sh | |
| **7065** | | |
| **7065** | | |
| **7071** | | |
| **7067** | | |
| **7065** | 7170sh | |
| **7065** | | |
| **7065** | 7170sh | |
| **7062** | | |
| **7066** | | |
| **7066** | | |
| **7068** | | |
| **7070** | | ~7215 |
| **7066** | 7170sh | |
| **7070** | | |
| **7070** | | |
| **7066** | | ~7215? |
| **7067** | | |
| **7075** | | |
| **7075** | | |
| **7071** | | |
| **7065** | | |
| **7072** | ~7082 | ~7215 |
| **7070** | | ~7215 |

Appendix III - Supplementary Table 2. Oxide wt% results and calculated structural formula of illite crystals from fossils

| Oxides wt% | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 56,20 | 55,33 | 56,61 | 60,34 | 56,59 | 62,43 | 56,82 | 56,75 | 56,09 | 54,60 | 55,60 | 58,66 |
| $Al_2O_3$ | 29,56 | 30,24 | 31,15 | 27,06 | 30,22 | 25,16 | 30,27 | 30,30 | 31,19 | 32,01 | 31,02 | 27,52 |
| FeO | - | - | - | - | - | - | - | - | - | - | - | - |
| $Fe_2O_3$ | 5,05 | 4,94 | 3,58 | 4,00 | 4,40 | 4,25 | 3,96 | 4,46 | 4,03 | 3,94 | 4,02 | 4,62 |
| MgO | 1,22 | 1,34 | 1,11 | 1,25 | 1,24 | 1,08 | 0,97 | 1,18 | 1,40 | 1,25 | 1,14 | 1,37 |
| $TiO_2$ | 0,19 | 0,25 | 0,16 | 0,34 | 0,17 | 0,31 | 0,09 | 0,09 | 0,00 | 0,26 | 0,34 | 0,34 |
| MnO | 0,00 | 0,00 | 0,07 | 0,00 | 0,03 | 0,02 | 0,00 | 0,00 | 0,00 | 0,06 | 0,06 | 0,02 |
| CaO | 0,13 | 0,10 | 0,08 | 0,10 | 0,11 | 0,09 | 0,07 | 0,04 | 0,03 | 0,07 | 0,10 | 0,18 |
| $Na_2O$ | 0,09 | 0,09 | 0,08 | 0,04 | 0,09 | 0,13 | 0,00 | 0,12 | 0,11 | 0,08 | 0,10 | 0,13 |
| $K_2O$ | 8,06 | 8,19 | 7,40 | 7,17 | 7,55 | 6,95 | 8,20 | 7,52 | 7,55 | 8,07 | 8,00 | 7,39 |
| Total | 101 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Numbers of cations on the basis of 11 oxygens | | | | | | | | | | | | |
| Si | 3,47 | 3,42 | 3,47 | 3,68 | 3,48 | 3,79 | 3,50 | 3,49 | 3,45 | 3,37 | 3,43 | 3,60 |
| $Al^{IV}$ | 0,53 | 0,58 | 0,53 | 0,32 | 0,52 | 0,21 | 0,50 | 0,51 | 0,55 | 0,63 | 0,57 | 0,40 |
| ∑Tet | 4,00 | 4,00 | 4,00 | 4,00 | 4,00 | 4,00 | 4,00 | 4,00 | 4,00 | 4,00 | 4,00 | 4,00 |
| $Al^{VI}$ | 1,63 | 1,63 | 1,72 | 1,62 | 1,67 | 1,59 | 1,70 | 1,68 | 1,71 | 1,70 | 1,68 | 1,59 |
| $Fe^{+3}$ | 0,23 | 0,23 | 0,17 | 0,18 | 0,20 | 0,19 | 0,18 | 0,21 | 0,19 | 0,18 | 0,19 | 0,21 |
| $Fe^{+2}$ | - | - | - | - | - | - | - | - | - | - | - | - |
| Mg | 0,11 | 0,12 | 0,10 | 0,11 | 0,11 | 0,10 | 0,09 | 0,11 | 0,13 | 0,12 | 0,10 | 0,13 |
| Ti | 0,01 | 0,02 | 0,01 | 0,03 | 0,01 | 0,02 | 0,01 | 0,01 | 0,00 | 0,02 | 0,03 | 0,03 |
| Mn | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| ∑Oct | 1,99 | 2,00 | 2,01 | 1,94 | 2,00 | 1,91 | 1,98 | 2,00 | 2,02 | 2,02 | 2,00 | 1,96 |
| Ca | 0,01 | 0,01 | 0,01 | 0,01 | 0,01 | 0,01 | 0,00 | 0,00 | 0,00 | 0,00 | 0,01 | 0,01 |
| Na | 0,01 | 0,01 | 0,01 | 0,00 | 0,01 | 0,01 | 0,00 | 0,01 | 0,01 | 0,01 | 0,01 | 0,02 |
| K | 0,64 | 0,65 | 0,58 | 0,56 | 0,59 | 0,54 | 0,64 | 0,59 | 0,59 | 0,64 | 0,63 | 0,58 |
| ∑Int. | 0,66 | 0,66 | 0,59 | 0,57 | 0,61 | 0,56 | 0,65 | 0,61 | 0,61 | 0,65 | 0,65 | 0,61 |

All Fe has been considered as $Fe^{3+}$. Tet = tetrahedral occupancy; Oct = octahedral

Appendix III - Supplementary Table 2. *Cont.*

| 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 53,23 | 61,66 | 66,43 | 56,30 | 58,24 | 59,32 | 56,56 | 59,33 | 54,17 | 56,01 | 62,62 | 60,03 | 57,38 | 55,08 |
| 31,83 | 25,88 | 22,37 | 29,61 | 28,67 | 27,06 | 29,22 | 26,05 | 30,95 | 29,11 | 23,79 | 26,46 | 26,66 | 29,33 |
| - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4,82 | 4,01 | 3,48 | 4,09 | 3,71 | 3,51 | 4,15 | 4,90 | 4,01 | 4,75 | 4,52 | 4,03 | 5,40 | 5,19 |
| 1,36 | 1,03 | 0,98 | 1,21 | 1,33 | 1,30 | 1,02 | 1,17 | 1,34 | 1,49 | 1,20 | 1,05 | 1,59 | 1,27 |
| 0,18 | 0,24 | 0,37 | 0,17 | 0,23 | 0,32 | 0,34 | 0,29 | 0,26 | 0,41 | 0,16 | 0,25 | 0,40 | 0,33 |
| 0,00 | 0,02 | 0,05 | 0,00 | 0,02 | 0,00 | 0,00 | 0,00 | 0,02 | 0,01 | 0,03 | 0,04 | 0,00 | 0,00 |
| 0,00 | 0,00 | 0,06 | 0,08 | 0,00 | 0,00 | 0,02 | 0,03 | 0,00 | 0,01 | 0,07 | 0,01 | 0,00 | 0,02 |
| 0,13 | 0,08 | 0,12 | 0,06 | 0,09 | 0,07 | 0,10 | 0,10 | 0,07 | 0,10 | 0,06 | 0,11 | 0,08 | 0,10 |
| 8,46 | 7,09 | 6,14 | 8,49 | 7,70 | 8,42 | 8,60 | 8,13 | 9,18 | 8,12 | 7,55 | 8,03 | 8,49 | 8,67 |
| 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| | | | | | | | | | | | | | |
| 3,32 | 3,76 | 4,00 | 3,49 | 3,58 | 3,65 | 3,51 | 3,67 | 3,38 | 3,47 | 3,84 | 3,69 | 3,57 | 3,44 |
| 0,68 | 0,24 | 0,00 | 0,51 | 0,42 | 0,35 | 0,49 | 0,33 | 0,62 | 0,53 | 0,16 | 0,31 | 0,43 | 0,56 |
| 4,00 | 4,00 | 4,00 | 4,00 | 4,00 | 4,00 | 4,00 | 4,00 | 4,00 | 4,00 | 4,00 | 4,00 | 4,00 | 4,00 |
| 1,67 | 1,62 | 1,58 | 1,66 | 1,66 | 1,62 | 1,64 | 1,56 | 1,66 | 1,60 | 1,55 | 1,61 | 1,52 | 1,60 |
| 0,23 | 0,18 | 0,16 | 0,19 | 0,17 | 0,16 | 0,19 | 0,23 | 0,19 | 0,22 | 0,21 | 0,19 | 0,25 | 0,24 |
| - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 0,13 | 0,09 | 0,09 | 0,11 | 0,12 | 0,12 | 0,09 | 0,11 | 0,12 | 0,14 | 0,11 | 0,10 | 0,15 | 0,12 |
| 0,01 | 0,02 | 0,03 | 0,01 | 0,02 | 0,02 | 0,03 | 0,02 | 0,02 | 0,03 | 0,01 | 0,02 | 0,03 | 0,03 |
| 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| 2,03 | 1,92 | 1,86 | 1,97 | 1,97 | 1,92 | 1,96 | 1,92 | 1,99 | 1,99 | 1,89 | 1,91 | 1,95 | 1,98 |
| 0,00 | 0,00 | 0,00 | 0,01 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| 0,02 | 0,01 | 0,01 | 0,01 | 0,01 | 0,01 | 0,01 | 0,01 | 0,01 | 0,01 | 0,01 | 0,01 | 0,01 | 0,01 |
| 0,67 | 0,55 | 0,47 | 0,67 | 0,60 | 0,66 | 0,68 | 0,64 | 0,73 | 0,64 | 0,59 | 0,63 | 0,67 | 0,69 |
| 0,69 | 0,56 | 0,49 | 0,68 | 0,61 | 0,67 | 0,69 | 0,65 | 0,74 | 0,66 | 0,60 | 0,64 | 0,68 | 0,70 |

Appendix III - Supplementary Table 2. *Cont.*

| 27 | 28 | 29 | 30 |
|---|---|---|---|
| 57,29 | 61,72 | 55,86 | 59,36 |
| 28,54 | 24,70 | 29,24 | 29,74 |
| - | - | - | - |
| 5,22 | 4,62 | 4,35 | 2,93 |
| 1,20 | 1,38 | 1,52 | 1,08 |
| 0,52 | 0,16 | 0,16 | 0,11 |
| 0,04 | 0,00 | 0,00 | 0,01 |
| 0,06 | 0,07 | 0,05 | 0,03 |
| 0,07 | 0,05 | 0,06 | 0,64 |
| 7,07 | 7,30 | 8,76 | 6,11 |
| 100 | 100 | 100 | 100 |
| | | | |
| 3,53 | 3,78 | 3,48 | 3,61 |
| 0,47 | 0,22 | 0,52 | 0,39 |
| 4,00 | 4,00 | 4,00 | 4,00 |
| 1,60 | 1,56 | 1,62 | 1,74 |
| 0,24 | 0,21 | 0,20 | 0,13 |
| - | - | - | - |
| 0,11 | 0,13 | 0,14 | 0,10 |
| 0,04 | 0,01 | 0,01 | 0,01 |
| 0,00 | 0,00 | 0,00 | 0,00 |
| 1,99 | 1,92 | 1,98 | 1,98 |
| 0,00 | 0,00 | 0,00 | 0,00 |
| 0,01 | 0,01 | 0,01 | 0,07 |
| 0,55 | 0,57 | 0,70 | 0,47 |
| 0,57 | 0,58 | 0,71 | 0,55 |

Appendix III - Supplementary Table 3. Raman fitting results for the fossil and cement/matrix (C/M) clay minerals, and detrital micas

| Mineral/Structure | Centre | Width | Area | Centre | Width | Area | Centre | Width | Area | Centre | Width |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C/M | 129,386 | 7,97508 | 952719 | | | | 149,663 | 22,1699 | 941262 | | |
| C/M | 129,104 | 6,31943 | 783621 | 146,224 | 7,43827 | 164051 | | | | 154,649 | 14,3316 |
| C/M | 127,676 | 8,554 | 1,44E+06 | | | | 151,829 | 20,6853 | 315809 | | |
| C/M | 129,159 | 6,28984 | 684786 | 144,769 | 5,43862 | 118825 | 149,667 | 10,3926 | 141230 | | |
| C/M | 129,203 | 6,74691 | 1,64E+06 | 148,093 | 19,6143 | 629523 | | | | | |
| C/M | 129,292 | 7,25242 | 1,39E+06 | 145,237 | 21,1994 | 3,24E+06 | | | | | |
| C/M | 129,495 | 6,63278 | 1,26E+06 | 147,534 | 8,38337 | 124347 | | | | | |
| C/M | 129,336 | 6,18041 | 508175 | 144,773 | 6,85297 | 134649 | 152,517 | 12,8342 | 177612 | | |
| C/M | 129,163 | 7,91477 | 1,28E+06 | 147,527 | 9,59184 | 215956 | | | | 157,022 | 9,59184 |
| C/M | 129,693 | 6,50796 | 898010 | 144,796 | 8,4336 | 433761 | 149,526 | 15,2699 | 261519 | | |
| C/M | | | | 144,983 | 8,98975 | 771373 | 153,238 | 13,2126 | 304251 | | |
| C/M | 128,858 | 5,28012 | 166049 | 145,839 | 10,607 | 2,57E+06 | | | | | |
| C/M | 129,498 | 6,39541 | 819102 | 145,047 | 8,87969 | 978005 | | | | | |
| C/M | 129,574 | 6,67476 | 1,75E+06 | | | | | | | | |
| C/M | 129,214 | 6,74589 | 1,28E+06 | | | | | | | | |
| C/M | 129,546 | 7,02453 | 1,22E+06 | 144,632 | 9,72427 | 1,87E+06 | | | | | |
| C/M | 129,301 | 6,7904 | 1,16E+06 | 149,154 | 9,33432 | 105090 | | | | | |
| C/M | 128,71 | 6,43878 | 511166 | 145,961 | 7,69446 | 374926 | 152,708 | 12,1833 | 242972 | | |
| C/M | 128,861 | 6,64692 | 676934 | 146,68 | 9,72464 | 781383 | | | | 157,42 | 12,8934 |
| C/M | 129,566 | 7,90206 | 1,18E+06 | 145,412 | 10,7551 | 1,62E+07 | | | | | |
| C/M | 128,709 | 7,39782 | 980836 | 146,179 | 11,5853 | 2,20E+06 | | | | | |
| C/M | 129,412 | 5,05224 | 199583 | 146,405 | 10,9618 | 8,95E+06 | | | | | |
| C/M | 129,348 | 7,04772 | 1,20E+06 | 146,066 | 10,3627 | 7,43E+06 | | | | | |
| C/M | 129,221 | 6,91541 | 722762 | 145,587 | 9,9584 | 2,64E+06 | | | | | |
| C/M | 129,787 | 7,62905 | 321987 | 146,214 | 13,2876 | 1,58E+06 | | | | | |
| C/M | 129,967 | 6,32857 | 263331 | 146,431 | 5,5925 | 27508,2 | | | | 154,331 | 10,6933 |
| C/M | 129,757 | 5,62866 | 42812 | 146,862 | 8,71827 | 118003 | | | | 155,958 | 14,0511 |
| C/M | 129,961 | 5,49947 | 114779 | 146,724 | 10,1025 | 922236 | | | | | |
| C/M | 129,852 | 6,18981 | 192128 | 146,751 | 7,76327 | 75965,9 | | | | 155,746 | 10,9328 |
| C/M | 129,694 | 6,32842 | 218836 | 146,322 | 7,68103 | 90975,6 | | | | 154,055 | 12,5254 |
| C/M | 129,694 | 5,6709 | 126276 | 145,505 | 7,19097 | 108443 | 152,548 | 12,6567 | 119131 | | |
| C/M | | | | 146,662 | 10,8679 | 1,12E+06 | | | | | |
| C/M | 129,761 | 4,62238 | 47130,8 | 146,164 | 9,87262 | 1,08E+06 | | | | | |
| C/M | 128,916 | 6,5703 | 112763 | 146,203 | 8,14737 | 107533 | 153,226 | 12,3607 | 78574,2 | | |
| C/M | | | | 145,374 | 10,8479 | 5,38E+06 | | | | | |
| C/M | 129,759 | 5,59982 | 86765,1 | 147,089 | 11,2848 | 599267 | | | | | |
| C/M | 129,773 | 6,26316 | 195939 | 146,146 | 7,84083 | 156358 | 153,902 | 10,5144 | 69402,1 | | |
| C/M | 129,814 | 5,71142 | 108980 | 146,813 | 11,281 | 1,26E+06 | | | | | |
| C/M | 129,529 | 6,05063 | 199803 | 146,391 | 7,70953 | 128800 | 154,979 | 12,0575 | 119289 | | |
| C/M | 129,522 | 6,27029 | 142411 | 146,193 | 7,84923 | 107805 | 153,184 | 12,8826 | 118794 | | |
| C/M | 129,151 | 7,50969 | 233918 | | | | 153,664 | 14,2401 | 166645 | | |
| C/M | 129,408 | 5,68092 | 71438,4 | | | | 151,556 | 17,0172 | 295774 | | |
| C/M | 129,286 | 6,81552 | 314241 | | | | | | | | |
| C/M | 129,58 | 6,02224 | 114844 | 145,642 | 8,68336 | 321960 | | | | 154,052 | 10,5142 |
| C/M | 129,78 | 5,83179 | 100072 | 145,571 | 8,5516 | 411179 | | | | 153,29 | 14,0185 |
| C/M | 129,283 | 6,38666 | 152535 | 146,197 | 8,1254 | 110531 | | | | 154,346 | 13,4958 |
| C/M | 129,697 | 5,12219 | 72921,9 | 145,709 | 8,6519 | 475848 | | | | 154,205 | 12,8919 |
| C/M | 129,086 | 6,97068 | 187769 | | | | 151,719 | 14,324 | 88940,1 | | |
| C/M | 129,77 | 6,3518 | 342712 | | | | 152,867 | 12,9592 | 93272 | | |
| C/M | 128,68 | 4,5899 | 55715,5 | 147,368 | 10,8071 | 744460 | | | | | |
| C/M | 129,234 | 4,9173 | 74311,6 | 146,931 | 11,6376 | 786950 | | | | | |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **C/M** | | | | 146,151 | 11,6355 | 2,99E+06 | | | | | |
| **C/M** | 129,618 | 5,59928 | 108481 | 145,802 | 10,3068 | 833871 | | | | | |
| **C/M** | | | | 145,726 | 10,797 | 1,00E+07 | | | | | |
| **C/M** | | | | 145,516 | 10,7202 | 1,69E+07 | | | | | |
| **C/M** | 129,363 | 6,29426 | 185494 | | | | 151,063 | 13,7892 | 110264 | | |
| **C/M** | 128,916 | 6,54677 | 256432 | 146,42 | 7,37895 | 95642,4 | 153,967 | 11,3371 | 104512 | | |
| **C/M** | 129,302 | 6,4682 | 169058 | | | | 152,997 | 16,3033 | 336710 | | |
| **C/M** | 129,071 | 6,14589 | 75875,9 | 145,447 | 7,97111 | 119118 | | | | 154,641 | 14,3559 |
| **C/M** | 129,736 | 5,87057 | 124061 | 145,316 | 7,80162 | 138661 | 153,155 | 13,3014 | 180097 | | |
| **C/M** | 128,992 | 6,62715 | 140168 | 147,044 | 9,09668 | 108660 | | | | 155,742 | 11,0883 |
| **C/M** | 129,983 | 5,45274 | 67796 | 146,19 | 8,45124 | 103395 | | | | 155,071 | 13,2586 |
| **C/M** | 129,489 | 5,79998 | 148195 | 145,583 | 7,87253 | 199851 | 153,028 | 13,3651 | 175014 | | |
| **C/M** | 129,382 | 6,4496 | 302174 | | | | | | | 155,17 | 13,86 |
| **C/M** | 129,765 | 4,97152 | 87516 | 145,308 | 7,84894 | 246515 | 153,271 | 14,1441 | 233082 | | |
| **C/M** | 129,656 | 5,72743 | 130690 | 145,54 | 7,69071 | 165643 | 153,112 | 12,6614 | 131104 | | |
| **C/M** | 129,316 | 6,32229 | 82861,5 | | | | 152,252 | 17,1302 | 218147 | | |
| **C/M** | | | | 146,226 | 9,24894 | 579049 | | | | 155,981 | 11,99 |
| **C/M** | | | | 146,028 | 8,95294 | 648332 | | | | 155,154 | 14,0278 |
| **C/M** | | | | 145,993 | 10,2193 | 2,20E+06 | | | | | |
| **C/M** | | | | 147,603 | 11,9917 | 1,19E+06 | | | | | |
| **C/M** | | | | 147,974 | 12,1456 | 944742 | | | | | |
| **C/M** | | | | 146,566 | 9,61069 | 677582 | | | | 155,059 | 13,7269 |
| **C/M** | | | | 149,101 | 15,1026 | 838002 | | | | 159,256 | 7,40642 |
| **C/M** | | | | 145,943 | 10,0456 | 4,28E+06 | | | | | |
| **C/M** | | | | 146,317 | 10,3285 | 2,42E+06 | | | | | |
| **C/M** | | | | 147,009 | 11,4723 | 3,89E+06 | | | | | |
| **C/M** | | | | 145,789 | 10,3283 | 9,94E+06 | | | | | |
| **C/M** | 129,864 | 5,86095 | 98573,5 | 145,835 | 7,82479 | 256270 | | | | 154,77 | 14,5648 |
| **C/M** | | | | 146,118 | 10,2639 | 3,24E+06 | | | | | |
| **C/M** | 128,999 | 6,46085 | 84155,1 | 146,156 | 8,35749 | 302431 | | | | 154,484 | 14,6428 |
| **C/M** | 129,954 | 6,00195 | 141650 | 146,051 | 8,23056 | 195435 | | | | 154,816 | 14,2708 |
| **C/M** | | | | 146,413 | 10,5205 | 2,20E+06 | | | | | |
| **C/M** | | | | 145,656 | 8,46159 | 482267 | | | | 154,422 | 14,4958 |
| **C/M** | | | | 146,364 | 8,80254 | 678439 | | | | 155,395 | 13,0172 |
| **C/M** | | | | 146,431 | 9,26368 | 282958 | | | | 155,535 | 13,444 |
| **Fossil** | | | | 147,706 | 12,6714 | 1,21E+08 | | | | | |
| **Fossil** | 127,83 | 7,3457 | 683607 | 146,421 | 12,6497 | 7,49E+06 | | | | | |
| **Fossil** | | | | 148,615 | 13,1089 | 1,30E+07 | | | | | |
| **Fossil** | | | | 148,892 | 13,6585 | 1,03E+07 | | | | | |
| **Fossil** | | | | 148,763 | 13,0783 | 3,22E+07 | | | | | |
| **Fossil** | | | | 149,218 | 14,1319 | 5,48E+06 | | | | | |
| **Fossil** | | | | 147,806 | 12,791 | 2,49E+07 | | | | | |
| **Fossil** | | | | 148,901 | 13,8391 | 7,13E+06 | | | | | |
| **Fossil** | | | | 148,444 | 13,5484 | 4,15E+07 | | | | | |
| **Fossil** | | | | 148,769 | 13,3454 | 1,40E+07 | | | | | |
| **Fossil** | | | | 148,532 | 13,2999 | 1,19E+07 | | | | | |
| **Fossil** | | | | 148,017 | 12,4945 | 1,26E+07 | | | | | |
| **Fossil** | 127,372 | 9,34272 | 1,01E+06 | 147,567 | 12,8541 | 6,26E+06 | | | | | |
| **Fossil** | | | | 149,258 | 13,8485 | 2,04E+07 | | | | | |
| **Fossil** | | | | 149,631 | 13,905 | 3,78E+07 | | | | | |
| **Fossil** | 127,947 | 6,91114 | 783502 | 147,04 | 11,5526 | 7,67E+06 | | | | | |
| **Fossil** | | | | 148,241 | 13,4788 | 1,65E+07 | | | | | |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Fossil** | | | | 147,86 | 12,5082 | 7,12E+06 | | | | | |
| **Fossil** | | | | 147,542 | 12,1683 | 4,96E+07 | | | | | |
| **Fossil** | | | | 147,938 | 13,0232 | 1,41E+07 | | | | | |
| **Fossil** | | | | 147,638 | 12,5072 | 1,84E+07 | | | | | |
| **Fossil** | | | | 147,655 | 12,6328 | 1,25E+08 | | | | | |
| **Fossil** | | | | 148,324 | 13,2264 | 7,64E+06 | | | | | |
| **Fossil** | | | | 147,646 | 13,2451 | 2,33E+07 | | | | | |
| **Fossil** | 128,393 | 6,12363 | 329812 | 146,972 | 12,2083 | 7,35E+06 | | | | | |
| **Fossil** | | | | 147,736 | 12,6652 | 1,82E+07 | | | | | |
| **Fossil** | | | | 144,768 | 11,3537 | 1,52E+06 | | | | | |
| **Fossil** | | | | 143,946 | 9,13886 | 336299 | 151,062 | 15,99 | 202608 | | |
| **Fossil** | | | | 144,056 | 10,9045 | 3,38E+06 | | | | | |
| **Fossil** | | | | 143,964 | 8,78305 | 295571 | 152,098 | 15,0099 | 172732 | | |
| **Fossil** | | | | 145,021 | 11,0908 | 2,59E+06 | | | | | |
| **Fossil** | | | | 143,769 | 8,16879 | 252939 | 152,008 | 14,2293 | 98465 | | |
| **Fossil** | | | | 144,183 | 10,6878 | 1,45E+06 | | | | | |
| **Fossil** | | | | 145,159 | 10,9685 | 1,97E+06 | | | | | |
| **Fossil** | | | | 145,467 | 11,7954 | 701738 | | | | | |
| **Fossil** | | | | 144,42 | 9,36299 | 623559 | 152,723 | 13,76 | 211657 | | |
| **Fossil** | | | | 144,9 | 10892 | 7,19E+06 | | | | | |
| **Fossil** | 127,812 | 4,47556 | 53262,5 | 144,728 | 10,6631 | 2,81E+06 | | | | | |
| **Fossil** | | | | 145,08 | 11,3789 | 3,58E+06 | | | | | |
| **Fossil** | | | | 145,121 | 11,2145 | 3,05E+06 | | | | | |
| **Fossil** | | | | 148,216 | 13,4249 | 1,58E+06 | | | | | |
| **Fossil** | | | | 147,849 | 12,1212 | 2,61E+06 | | | | | |
| **Fossil** | | | | 147,122 | 11,6961 | 2,12E+06 | | | | | |
| **Fossil** | | | | 147,849 | 12,0049 | 2,52E+06 | | | | | |
| **Fossil** | | | | 147,562 | 12,389 | 3,41E+06 | | | | | |
| **Fossil** | | | | 147,983 | 12,995 | 5,65E+06 | | | | | |
| **Fossil** | | | | 147,651 | 12,1895 | 8,75E+06 | | | | | |
| **Fossil** | | | | 147,79 | 12,1298 | 2,86E+06 | | | | | |
| **Fossil** | | | | 147,788 | 12,6523 | 3,28E+06 | | | | | |
| **Fossil** | | | | 147,616 | 12,0732 | 2,63E+06 | | | | | |
| **Fossil** | | | | 148,214 | 13,1858 | 1,49E+06 | | | | | |
| **Fossil** | | | | 147,546 | 12,1994 | 5,55E+06 | | | | | |
| **Fossil** | | | | 147,904 | 12,5621 | 1,79E+06 | | | | | |
| **Fossil** | | | | 147,447 | 11,7926 | 6,65E+06 | | | | | |
| **Fossil** | | | | 148,199 | 12,9601 | 3,57E+06 | | | | | |
| **Fossil** | | | | 147,823 | 12,5943 | 2,14E+06 | | | | | |
| **Fossil** | | | | 146,896 | 12,028 | 2,22E+06 | | | | | |
| **Fossil** | | | | 147,083 | 12,1146 | 2,89E+06 | | | | | |
| **Fossil** | | | | 147,113 | 11,8607 | 1,95E+06 | | | | | |
| **Fossil** | | | | 147,645 | 13,1702 | 4,66E+06 | | | | | |
| **Fossil** | | | | 146,519 | 12,074 | 3,34E+06 | | | | | |
| **Fossil** | | | | 146,36 | 9,9252 | 800702 | | | | 154,731 | 14,0264 |
| **Fossil** | | | | 146,774 | 11,9863 | 4,74E+06 | | | | | |
| **Fossil** | | | | 148,169 | 12,4547 | 6,72E+06 | | | | | |
| **Fossil** | | | | 146,867 | 11,6595 | 8,04E+06 | | | | | |
| **Fossil** | | | | 146,868 | 11,6776 | 8,03E+06 | | | | | |
| **Fossil** | | | | 146,751 | 11,5009 | 2,72E+06 | | | | | |
| **Fossil** | | | | 147,413 | 12,0608 | 1,43E+06 | | | | | |
| **Fossil** | | | | 147,412 | 12,0584 | 1,43E+06 | | | | | |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Fossil** | | 147,424 | 12,1579 | 3,02E+06 | | | | | |
| **Fossil** | | 147,542 | 12,1892 | 2,93E+06 | | | | | |
| **Fossil** | | 147,306 | 12,103 | 3,81E+06 | | | | | |
| **Fossil** | | 147,345 | 11,6679 | 2,39E+06 | | | | | |
| **Fossil** | | 147,345 | 11,667 | 2,40E+06 | | | | | |
| **Fossil** | | 147,698 | 12,3435 | 2,62E+06 | | | | | |
| **Fossil** | | 148,216 | 13,0601 | 1,05E+07 | | | | | |
| **Fossil** | | 148,064 | 12,862 | 1,86E+06 | | | | | |
| **Fossil** | | 147,924 | 12,1069 | 1,36E+06 | | | | | |
| **Fossil** | | 149,01 | 13,3615 | 808676 | | | | | |
| **Fossil** | | 147,692 | 11,2304 | 1,09E+06 | | | | | |
| **Fossil** | | 147,724 | 112479 | 1,25E+06 | | | | | |
| **Fossil** | | 147,924 | 12,2787 | 9,70E+06 | | | | | |
| **Fossil** | | 147,917 | 12,0997 | 2,03E+06 | | | | | |
| **Fossil** | | 147,507 | 12,1735 | 3,74E+06 | | | | | |
| **Fossil** | | 147,645 | 11,8443 | 1,46E+06 | | | | | |
| **Fossil** | | 147,212 | 11,1336 | 3,43E+06 | | | | | |
| **Fossil** | | 147,891 | 12,2979 | 2,20E+06 | | | | | |
| **Fossil** | | 147,982 | 12,3151 | 1,41E+06 | | | | | |
| **Fossil** | | 148,284 | 12,8794 | 1,46E+06 | | | | | |
| **Fossil** | | 149,137 | 13,5574 | 1,42E+06 | | | | | |
| **Fossil** | | 148,259 | 12,4964 | 2,19E+06 | | | | | |
| **Fossil** | | 148,113 | 12,675 | 1,46E+06 | | | | | |
| **Fossil** | | 147,525 | 11,3744 | 2,26E+06 | | | | | |
| **Fossil** | | 147,563 | 11,4947 | 1,80E+06 | | | | | |
| **Fossil** | | 147,622 | 11,7108 | 1,91E+06 | | | | | |
| **Mica clast** | | | | | 150,733 | 17,8309 | 105184 | | |
| **Mica clast** | | | | | 149,767 | 16,2107 | 80313,2 | | |
| **Mica clast** | | | | | 152,682 | 17,9995 | 92517,7 | | |
| **Mica clast** | | 143,987 | 9,26545 | 482470 | | | | 155,298 | 16,2715 |
| **Mica clast** | | | | | 152,112 | 18,3915 | 305673 | | |
| **Mica clast** | | 143,896 | 11,1251 | 2,74E+06 | | | | | |
| **Mica clast** | | | | | | | | | |
| **Mica clast** | | | | | 149,892 | 16,2581 | 125263 | | |
| **Mica clast** | | | | | 151,578 | 17,3694 | 141005 | | |
| **Mica clast** | | | | | 149,008 | 17,0228 | 129583 | | |
| **Mica clast** | | 143,636 | 8,51843 | 133815 | 152,744 | 15,8381 | 147644 | | |
| **Mica clast** | | 144,655 | 8,02256 | 71458,8 | 152,844 | 142161 | 178976 | | |
| **Mica clast** | | | | | 151,162 | 18,5717 | 269572 | | |
| **Mica clast** | | 144,06 | 7,62159 | 99767,7 | 152,266 | 14,1953 | 78292,8 | | |
| **Mica clast** | | 144,349 | 8,08032 | 189069 | 152,277 | 14,4594 | 83180 | | |
| **Mica clast** | | | | | 151,572 | 17,4123 | 71062,3 | | |
| **Mica clast** | | | | | | | | | |
| **Mica clast** | | 144,633 | 7,01784 | 40892,1 | 151,354 | 12,2784 | 44516,3 | | |
| **Mica clast** | | 145,406 | 7,41524 | 38546,1 | 153,923 | 13,8271 | 32693,7 | | |
| **Mica clast** | | 145,766 | 9,17852 | 62785,8 | | | | 156,532 | 18,376 |
| **Mica clast** | | 145,581 | 9,36284 | 123152 | | | | 154,969 | 13,8707 |
| **Mica clast** | | | | | | | | | |

Appendix III - Supplementary Table 3. *Cont.*

| Area | Centre | Width | Area | Centre | Width | Area | Centre | Width | Area | Centre | Width | Area | Centre |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 195,837 | 17,2271 | 1,98E+06 | |
| 347169 | | | | | | | | | | | | | 203,819 |
| | | | | | | | | | | | | | 204,662 |
| | | | | | | | | | | 193,504 | 15,8793 | 867493 | 208,264 |
| | | | | | | | | | | | | | 204,568 |
| | | | | | | | | | | | | | 206,009 |
| | | | | | | | | | | | | | 205,915 |
| | | | | | | | | | | | | | 203,259 |
| 110958 | | | | | | | | | | | | | 204,955 |
| | | | | | | | | | | 190,252 | 13,8311 | 227087 | 205,737 |
| | | | | | | | | | | 194,53 | 16,8079 | 1,82E+06 | |
| | | | | | | | | | | 194,342 | 16,1193 | 1,52E+06 | |
| | | | | | | | | | | | | | 203,928 |
| | | | | | | | | | | | | | 207,189 |
| | | | | | | | | | | | | | 204,318 |
| | | | | | | | | | | 192,457 | 15,4654 | 537460 | 206,337 |
| | | | | | | | | | | | | | 205,648 |
| | | | | | | | | | | | | | 202,216 |
| 872128 | | | | | | | | | | | | | 203,322 |
| | | | | | | | | | | | | | 204,966 |
| | | | | | | | | | | | | | 202,973 |
| | | | | | | | | | | | | | 203,668 |
| | | | | | | | | | | | | | 205,303 |
| | | | | | | | | | | | | | 203,828 |
| | | | | | | | | | | | | | 204,761 |
| 55174,5 | | | | | | | | | | | | | 205,544 |
| 169605 | | | | | | | | | | | | | 201,693 |
| | | | | | | | | | | | | | 205,187 |
| 56574,6 | | | | | | | | | | | | | 204,621 |
| 98693 | | | | | | | | | | | | | 205,039 |
| | | | | | | | | | | | | | 203,483 |
| | | | | | | | | | | | | | 202,763 |
| | | | | | | | | | | | | | 203,431 |
| | | | | | | | | | | | | | 202,744 |
| | | | | | | | | | | | | | 198,466 |
| | | | | | | | | | | | | | 205,15 |
| | | | | | | | | | | | | | 205,339 |
| | | | | | | | | | | | | | 204,661 |
| | | | | | | | | | | | | | 204,254 |
| | | | | | | | | | | | | | 204,514 |
| | | | | | | | | | | | | | 203,271 |
| | | | | | | | | | | | | | 201,831 |
| | | | | | | | | | | | | | 206,649 |
| 110771 | | | | | | | | | | | | | 203,326 |
| 250594 | | | | | | | | | | | | | 204,285 |
| 135379 | | | | | | | | | | | | | 203,368 |
| 223648 | | | | | | | | | | | | | 203,491 |
| | | | | | | | | | | | | | 204,087 |
| | | | | | | | | | | | | | 205,716 |
| | | | | | | | | | | | | | 202,57 |
| | | | | | | | | | | | | | 203,235 |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | 204,152 |
| | | | | | | | 204,272 |
| | | | | | | | 203,38 |
| | | | | | | | 199,033 |
| | | | | | | | 203,986 |
| | | | | | | | 204,426 |
| | | | | | | | 203,834 |
| 221276 | | | | | | | 202,205 |
| | | | | | | | 204,457 |
| 78208,3 | | | | | | | 202,234 |
| 155088 | | | | | | | 202,472 |
| | | | | | | | 204,451 |
| 568346 | | | | | | | 204,926 |
| | | | | | | | 203,366 |
| | | | | | | | 203,997 |
| | | | | | | | 202,01 |
| 206407 | | | | | | | 203,481 |
| 422688 | | | | | | | 201,802 |
| | | | | | | | 202,889 |
| | | | | | | | 196,188 |
| | | | | | | | 201,165 |
| 237863 | | | | | | | 202,387 |
| 59852 | | | | | | | 202,577 |
| | | | | | | | 202563 |
| | | | | | | | 202,68 |
| | | | | | | | 202,597 |
| | | | | | | | 198,025 |
| 423238 | | | | | | | 203,584 |
| | | | | | | | 203,777 |
| 315178 | | | | | | | 202,388 |
| 267556 | | | | | | | 204,155 |
| | | | | | | | 203,164 |
| 356412 | | | | | | | 201,927 |
| 358886 | | | | | | | 202,56 |
| 341388 | | | | | | | 201,932 |
| | | | | | | | 200,366 |
| | | | | 194,677 | 16,003 | 1,30E+06 | 207,414 |
| | | | | 195,83 | 17,9532 | 1,74E+06 | |
| | | | | | | | 199,509 |
| | | | | | | | 201,69 |
| | | | | 192,752 | 14,2648 | 568099 | 205,252 |
| | | | | | | | 200,7 |
| | | | | | | | 201,308 |
| | | | | | | | 200,449 |
| | | | | | | | 200,133 |
| | | | | | | | 199,814 |
| | | | | | | | 199,689 |
| | | | | 195,704 | 17,573 | 1,71E+06 | |
| | | | | | | | 200,462 |
| | | | | | | | 201,795 |
| | | | | | | | 200,937 |
| | | | | | | | 199,759 |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | 194,768 | 15,6372 | 997517 | |
| | | | | | | | 199,523 |
| | | | | | | | 197,89 |
| | | | | | | | 201,932 |
| | | | | | | | 200,333 |
| | | | | 195,499 | 14,6122 | 838113 | 206,989 |
| | | | | | | | 199,169 |
| | | | | | | | 196,408 |
| | | | | | | | 198,022 |
| | | | | | | | 200,162 |
| | | | | | | | 199,539 |
| | | | | | | | 196,39 |
| | | | | | | | 199,581 |
| | | | | | | | 198,955 |
| | | | | | | | 201,491 |
| | | | | | | | 200,135 |
| | | | | | | | 199,086 |
| | | | | 193,63 | 15,2577 | 231814 | 206,892 |
| | | | | | | | 198,971 |
| | | | | | | | 197,124 |
| | | | | | | | 201,775 |
| | | | | | | | 197,136 |
| | | | | | | | 199,012 |
| | | | | | | | 198,861 |
| | | | | | | | 200,441 |
| | | | | | | | 196,116 |
| | | | | 195,673 | 16,6932 | 406028 | |
| | | | | 195,239 | 15,2435 | 357349 | 206,913 |
| | | | | | | | 200,878 |
| | | | | | | | 198,345 |
| | | | | 196,192 | 17,0799 | 491065 | |
| | | | | | | | 200,753 |
| | | | | 195,731 | 16,8904 | 463123 | |
| | | | | | | | 199,105 |
| | | | | | | | 201,344 |
| | | | | 194,801 | 15,725 | 292789 | 206,55 |
| | | | | | | | 198,17 |
| | | | | | | | 200,221 |
| | | | | | | | 201,297 |
| | | | | | | | 199,448 |
| | | | | | | | 200,801 |
| | | | | | | | 199,573 |
| | | | | | | | 200,15 |
| | | | | | | | 199,931 |
| 428908 | | | | | | | 200,487 |
| | | | | | | | 200,796 |
| | | | | | | | 200,59 |
| | | | | | | | 201,358 |
| | | | | | | | 201,362 |
| | | | | | | | 201,72 |
| | | | | 194,61 | 15,6909 | 250919 | 206,914 |
| | | | | 194,614 | 15,6936 | 251172 | 206,926 |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | 200,531 |
| | | | | | | | 200,639 |
| | | | | | | | 200,678 |
| | | | | | | | 199,263 |
| | | | | | | | 199,225 |
| | | | | | | | 199,96 |
| | | | | | | | 201,073 |
| | | | | | | | 199,337 |
| | | | | | | | 201,776 |
| | | | | | | | 201,51 |
| | | | | | | | 202,251 |
| | | | | | | | 202,742 |
| | | | | | | | 198,264 |
| | | | | | | | 196,43 |
| | | | | | | | 197,66 |
| | | | | | | | 195,531 |
| | | | | | | | 197,912 |
| | | | | | | | 195,636 |
| | | | | | | | 197,01 |
| | | | | | | | 201,552 |
| | | | | | | | 201,379 |
| | | | | | | | 194,891 |
| | | | | | | | 200,694 |
| | | | | | | | 196,136 |
| | | | | | | | 195,749 |
| | | | | | | | 201,546 |
| | | | | | | | 198,3 |
| | | | | 190,633 | 19,3817 | 576736 | |
| | | | | 193,573 | 15,6033 | 94673,1 | |
| 141735 | | | | 194,611 | 17,3289 | 464640 | |
| | | | | | | | 203,605 |
| | | | | | | | 199,675 |
| | | | | | | | 198,995 |
| | | | | | | | 198,935 |
| | | | | | | | 198,164 |
| | | | | 193,915 | 13,995 | 63939,5 | |
| | | | | 193,283 | 14,829 | 116196 | |
| | | | | | | | 201,37 |
| | | | | | | | 199,528 |
| | | | | | | | 198,933 |
| | | | | | | | 197,436 |
| | | | | | | | 198,033 |
| | | | | 193,93 | 20,3038 | 423106 | |
| | | | | | | | 200,166 |
| | | | | | | | 198,089 |
| 86035,7 | | | | | | | 196,593 |
| 86691,2 | | | | | | | 196,316 |
| | | | | | | | 199,499 |

Appendix III - Supplementary Table 3. *Cont.*

| Width | Area | Centre | Width | Area | Centre | Width | Area | Centre | Width | Area | Centre | Width |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 210,719 | 18,6545 | 1,39E+06 | | | | | | | | |
| 25,9248 | 4,19E+06 | | | | | | | | | | | |
| 28,5133 | 6,11E+06 | | | | | | | | | | | |
| 19,9001 | 3,02E+06 | | | | | | | | | | | |
| 26,0807 | 5,39E+06 | | | | | | | | | | | |
| 24,076 | 5,11E+06 | | | | | | | | | | | |
| 26,4595 | 5,28E+06 | | | | | | | | | | | |
| 27,387 | 3,29E+06 | | | | | | | | | | | |
| 26,6264 | 5,41E+06 | | | | | | | | | | | |
| 25,1729 | 3,39E+06 | | | | | | | | | | | |
| | | 209,166 | 20,6802 | 1,32E+06 | | | | | | | | |
| | | 208,221 | 21,4 | 1,79E+06 | | | | | | | | |
| 27,1976 | 4,55E+06 | | | | | | | | | | | |
| 26,4799 | 1,03E+07 | | | | | | | | | | | |
| 27,1181 | 4,53E+06 | | | | | | | | | | | |
| 24,1542 | 3,91E+06 | | | | | | | | | | | |
| 29,3878 | 6,45E+06 | | | | | | | | | | | |
| 26,8554 | 3,17E+06 | | | | | | | | | | | |
| 27,4971 | 5,9971 | | | | | | | | | | | |
| 24,0912 | 4,08E+06 | | | | | | | | | | | |
| 27,1169 | 3,76E+06 | | | | | | | | | | | |
| 23,7921 | 1,95E+06 | | | | | | | | | | | |
| 25,2118 | 4,42E+06 | | | | | | | | | | | |
| 26,8966 | 3,91E+06 | | | | | | | | | | | |
| 24,3242 | 851247 | | | | | | | | | | | |
| 27,1022 | 1,15E+06 | | | | | | | | | | | |
| 26,862 | 721214 | | | | | | | | | | | |
| 26,6896 | 945978 | | | | | | | | | | | |
| 28,0085 | 1,14E+06 | | | | | | | | | | | |
| 27,2251 | 1,09E+06 | | | | | | | | | | | |
| 28,545 | 1,05E+06 | | | | | | | | | | | |
| 25,514 | 522754 | | | | | | | | | | | |
| 26,4077 | 777365 | | | | | | | | | | | |
| 27,7492 | 766354 | | | | | | | | | | | |
| 13,2085 | 252712 | 210,322 | 20,9102 | 474553 | | | | | | | | |
| 26,6349 | 693343 | | | | | | | | | | | |
| 27,1964 | 1,29E+06 | | | | | | | | | | | |
| 26,6452 | 880133 | | | | | | | | | | | |
| 27,4031 | 1,11E+06 | | | | | | | | | | | |
| 28,0939 | 1,08E+06 | | | | | | | | | | | |
| 26,8499 | 941559 | | | | | | | | | | | |
| 27,0028 | 954679 | | | | | | | | | | | |
| 29,9226 | 1,66E+06 | | | | | | | | | | | |
| 28,3811 | 1,17E+06 | | | | | | | | | | | |
| 27,0015 | 870779 | | | | | | | | | | | |
| 28,0008 | 977794 | | | | | | | | | | | |
| 27,4277 | 1,08E+06 | | | | | | | | | | | |
| 27,7243 | 928684 | | | | | | | | | | | |
| 27,2839 | 1,40E+06 | | | | | | | | | | | |
| 27,0173 | 958424 | | | | | | | | | | | |
| 27,8852 | 992640 | | | | | | | | | | | |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 23,7015 | 595672 | | | | | | | |
| 26,6242 | 863007 | | | | | | | |
| 25,3653 | 1,92E+06 | | | | | | | |
| 7,67064 | 181133 | 207,971 | 13,8523 | 257286 | | | | |
| 27,6476 | 1,23E+06 | | | | | | | |
| 29,7951 | 1,33E+06 | | | | | | | |
| 27,4871 | 1,39E+06 | | | | | | | |
| 26,9451 | 1,00E+06 | | | | | | | |
| 28,541 | 1,03E+06 | | | | | | | |
| 27,3712 | 898626 | | | | | | | |
| 27,2789 | 882731 | | | | | | | |
| 27,7892 | 1,25E+06 | | | | | | | |
| 26,562 | 1,15E+06 | | | | | | 248,853 | 6,87918 |
| 27,2996 | 1,14E+06 | | | | | | | |
| 280545 | 1,02E+06 | | | | | | | |
| 28105 | 896602 | | | | | | | |
| 27,6338 | 1,17E+06 | | | | | | | |
| 26,3041 | 971591 | | | | | | | |
| 26,3309 | 1,00E+06 | | | | | | | |
| 17,7122 | 457998 | 207,93 | 24,5244 | 773341 | | | | |
| 25,1787 | 1,17E+06 | | | | | | | |
| 26,9366 | 1,04E+06 | | | | | | | |
| 26,0854 | 1,23E+06 | | | | | | | |
| 25,3568 | 1,16E+06 | | | | | | | |
| 25,3227 | 1,06E+06 | | | | | | | |
| 24,4774 | 917625 | | | | | | | |
| 15,0941 | 495691 | 210,312 | 22,8186 | 483433 | | | | |
| 27,2824 | 1,38E+06 | | | | | | | |
| 26,4551 | 1,27E+06 | | | | | | | |
| 28,1033 | 1,10E+06 | | | | | | | |
| 28,198 | 1,29E+06 | | | | | | | |
| 27,1942 | 1,53E+06 | | | | | | | |
| 27,9663 | 1,06437E+11 | | | | | | | |
| 26,3425 | 1,36E+06 | | | | | | | |
| 26,3758 | 1,07E+06 | | | | | | | |
| 6,86192 | 1,00E+06 | | | | | | | |
| 22,2767 | 1,60E+06 | | | | | | | |
| | | 210,24 | 21,3422 | 953066 | | | | |
| 21,65 | 1,54E+06 | | | | | | | |
| 18,6666 | 2,29E+06 | | | | | | | |
| 20,1044 | 1,10E+06 | | | | | | | |
| 17,8326 | 1,69E+06 | | | | | | | |
| 10,5115 | 1,39E+06 | | | | | | | |
| 11,1296 | 999136 | | | | | | | |
| 18,5282 | 1,33E+06 | | | | | | | |
| 20,3926 | 1,41E+06 | | | | | | | |
| 20,309 | 1,66E+06 | | | | | | | |
| | | 211,37 | 24,379 | 1,11E+06 | | | | |
| 18,0398 | 1,63E+06 | | | | | | | |
| 12,5576 | 1,10E+06 | | | | | | | |
| 25,5405 | 3,69E+06 | | | | | | | |
| 18,8818 | 1,45E+06 | | | | | | | |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 207,637 | 20,2425 | 735868 | | | |
| 8,59094 | 831439 | 209,009 | 13,7992 | 343324 | | | |
| 13,6043 | 857127 | 211,066 | 14,941 | 288571 | | | |
| 20,3729 | 1,75E+06 | | | | | | |
| 6,39844 | 876240 | | | | | | |
| 17,7573 | 455309 | | | | | | |
| 16808 | 1,62E+06 | | | | | | |
| 15,9033 | 1,03E+06 | 209,091 | 21296 | 1,13E+06 | | | |
| 14,2192 | 1,25521E+11 | 213,364 | 14,1415 | 369142 | | | |
| 22,1542 | 167605 | | | | | | |
| 25,7335 | 337891 | | | | | | |
| 13,974 | 163831 | 209,179 | 16,3619 | 93116 | | | |
| 25,1609 | 307254 | | | | | | |
| 22,3408 | 420930 | | | | | | |
| 28,09 | 481870 | | | | | | |
| 23,6903 | 258142 | | | | | | |
| 24,3792 | 450757 | | | | | | |
| 20,456 | 235883 | | | | | | |
| 25,2173 | 600505 | | | | | | |
| 131354 | 311564 | 209,391 | 159434 | 191320 | | | |
| 24,955 | 779715 | | | | | | |
| 15,6501 | 330590 | 212,192 | 16,1625 | 149239 | | | |
| 22,3379 | 503151 | | | | | | |
| 23,4882 | 614630 | | | | | | |
| 22,8278 | 594269 | | | | | | |
| 17,2967 | 411541 | 210,895 | 21,277 | 258878 | | | |
| | | 209,268 | 20,4684 | 247632 | | | |
| 21,2118 | 444311 | | | | | | |
| 18,6032 | 520605 | | | | | | |
| 14,3767 | 463762 | 210,185 | 19,6523 | 293021 | | | |
| | | 208,357 | 22,8675 | 447447 | | | |
| 23,2041 | 774445 | | | | | | |
| | | 209,449 | 22,132 | 357233 | | | |
| 22,9592 | 607650 | | | | | | |
| 20,71 | 629281 | | | | | | |
| 20,4217 | 306245 | | | | | | |
| 15,4156 | 447922 | 210,116 | 21,1843 | 307515 | | | |
| 22,2956 | 798466 | | | | | | |
| 11,707 | 477016 | | | | | | |
| 24,2873 | 666398 | | | | | | |
| 25,2013 | 1,21E+06 | | | | | | |
| 24,7884 | 722637 | | | | | | |
| 21,9453 | 727475 | | | | | | |
| 21,2323 | 526621 | | | | | | |
| 25,7282 | 867552 | | | | | | |
| 20,1635 | 470148 | | | | | | |
| 19,6079 | 684695 | | | | | | |
| 19,5135 | 569016 | | | | | | |
| 19,6213 | 571603 | | | | | | |
| 23,6311 | 613287 | | | | | | |
| 21,5916 | 232242 | | | | | | |
| 21,5834 | 231962 | | | | | | |

Appendix III - Supplementary Table 3. *Cont.*

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 22,2648 | 557536 | | | | | | | | |
| 21,9997 | 474223 | | | | | | | | |
| 19,15 | 339058 | | | | | | | | |
| 23,0246 | 296487 | | | | | | | | |
| 22,8881 | 291058 | | | | | | | | |
| 22,7004 | 635812 | | | | | | | | |
| 11,4518 | 252449 | | | | | | | | |
| 20,4718 | 334552 | | | | | | | | |
| 26,3282 | 998225 | | | | | | | | |
| 26,1357 | 948693 | | | | | | | | |
| 27,2936 | 1,07E+06 | | | | | | | | |
| 28,1942 | 1,32E+06 | | | | | | | | |
| 14,5217 | 505252 | 209,916 | 20,6487 | 420263 | | | | | |
| 17,6056 | 489100 | 208,656 | 25,2359 | 596714 | | | | | |
| 17,6015 | 540470 | 210,447 | 24,903 | 452301 | | | | | |
| 17,3111 | 423220 | 208,106 | 25,6013 | 716131 | | | | | |
| 18,6817 | 561608 | 211,337 | 25,7693 | 483183 | | | | | |
| 17,5865 | 429892 | 207,49 | 24,6612 | 574781 | | | | | |
| 19,5168 | 533359 | 210,098 | 25,0247 | 373535 | | | | | |
| 25,4134 | 940716 | | | | | | | | |
| 26,3827 | 1,10E+06 | | | | | | | | |
| 17,0901 | 554017 | 207,394 | 24,8661 | 882368 | | | | | |
| 25,4133 | 1,17E+06 | | | | | | | | |
| 17,7274 | 573787 | 208,747 | 25,9422 | 928866 | | | | | |
| 17,6628 | 444755 | 207,799 | 24,86 | 718371 | | | | | |
| 25,9501 | 1,12E+06 | | | | | | | | |
| 18,2675 | 160687 | | | | 214,725 | 10,9533 | 46688,3 | | |
| | | 208,37 | 17,6206 | 122405 | | | | | |
| | | 208,821 | 16,9517 | 41884 | | | | | |
| | | | | | 213,823 | 15,2889 | 185963 | | |
| 26,8719 | 741794 | | | | | | | | |
| 19,0467 | 717765 | | | | 216,319 | 11,4933 | 256651 | | |
| 19,3825 | 797649 | | | | 216,462 | 11,4729 | 225833 | | |
| 18,5652 | 161098 | | | | 214,911 | 10,3949 | 46947,1 | | |
| 20,5955 | 219127 | | | | | | | | |
| | | 207,634 | 21,3382 | 69981,4 | | | | | |
| | | 206,923 | 21,3558 | 145536 | | | | | |
| 25538 | 368321 | | | | | | | | |
| 25,139 | 302189 | | | | | | | | |
| 17,9605 | 131215 | | | | 215,95 | 12,4967 | 54320,7 | | |
| 18,503 | 251433 | | | | 213,674 | 15,3909 | 101133 | | |
| 19,0323 | 206236 | | | | 216,416 | 14,1181 | 61221,1 | | |
| | | | | | 215,132 | 13,7382 | 43684,9 | | |
| 24,0655 | 195055 | | | | 217,685 | 9,79076 | 42924,7 | | |
| 16,873 | 137431 | | | | 215,351 | 12,2576 | 44251,4 | | |
| 13,3402 | 73743,3 | 211,806 | 16,5194 | 47156,5 | | | | | |
| 19,9734 | 245310 | | | | 213,087 | 16,3098 | 78678,2 | | |
| 17,1961 | 205042 | | | | 216,727 | 10,9123 | 57943,9 | | |

Appendix III - Supplementary Table 3. *Cont.*

| Area | Centre | Width | Area | Centre | Width | Area | Centre | Width | Area | Centre | Width | Area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 263,589 | 13,5622 | 5,18E+06 | | | | | | | | | |
| | 263,837 | 13,0096 | 2,47E+06 | | | | 285,15 | 19,5567 | 258772 | 333,244 | 17,0939 | 140068 |
| | 263,115 | 14,2567 | 3,06E+06 | | | | | | | | | |
| | 264 | 13,1056 | 1,75E+06 | | | | 290,948 | 10,2891 | 462660 | 330,752 | 9,24481 | 124607 |
| | 264,569 | 12,12 | 2,65E+06 | | | | | | | | | |
| | 264,693 | 10,528 | 1,65E+06 | | | | | | | | | |
| | 264,182 | 11,8781 | 1,62E+06 | | | | 289,249 | 13,7023 | 187440 | | | |
| | 263,962 | 13,0891 | 3,28E+06 | | | | | | | | | |
| | 264,191 | 11,1554 | 2,67E+06 | | | | | | | | | |
| | 264,057 | 13,1984 | 1,96E+06 | | | | 290,596 | 13,2113 | 378367 | | | |
| | 263,589 | 14,3377 | 5,24E+06 | | | | | | | | | |
| | 263,583 | 14,0667 | 4,87E+06 | | | | | | | | | |
| | 263,522 | 12,3221 | 3,26E+06 | | | | | | | | | |
| | 264,315 | 10,2336 | 1,35E+06 | | | | | | | | | |
| | 263,58 | 12,444 | 2,82E+06 | | | | | | | | | |
| | 263,567 | 12,5541 | 2,79E+06 | | | | | | | | | |
| | 263,616 | 12,7431 | 2,92E+06 | | | | | | | | | |
| | 263,641 | 12,9637 | 2,05E+06 | | | | 301,941 | 15,2047 | 269381 | | | |
| | 263,418 | 13,4154 | 2,75E+06 | | | | 287,746 | 14,8813 | 413947 | 335,05 | 20,1491 | 420216 |
| | 263,898 | 11,9158 | 1,49E+06 | | | | | | | | | |
| | 263,807 | 13,1016 | 2,16E+06 | | | | | | | | | |
| | 264,552 | 15,4418 | 1,46E+06 | | | | 291,175 | 12,2981 | 364584 | | | |
| | 264,084 | 11,7835 | 1,54E+06 | | | | | | | | | |
| | 263,454 | 13,1161 | 2,29E+06 | | | | 282,167 | 26,1906 | 225859 | 332,244 | 4,28109 | 12137,2 |
| | 264,534 | 13,0511 | 454509 | | | | | | | | | |
| | 264,438 | 12,2244 | 358065 | | | | | | | | | |
| | 265,269 | 14,4478 | 600819 | | | | | | | | | |
| | 264,552 | 12,1641 | 399623 | | | | | | | | | |
| | 264,424 | 12,5338 | 528015 | | | | | | | | | |
| | 264,752 | 11,6602 | 299193 | | | | | | | | | |
| | 264,491 | 13,1727 | 583555 | | | | | | | | | |
| | 264,78 | 13,9784 | 346748 | | | | | | | | | |
| | 264,978 | 13,1016 | 486529 | | | | | | | | | |
| | 264,638 | 12,995 | 479451 | | | | | | | | | |
| | 264,88 | 12,3554 | 375069 | | | | | | | | | |
| | 265,132 | 11,9055 | 246376 | | | | | | | | | |
| | 265,03 | 10,7051 | 229508 | | | | | | | | | |
| | 265,045 | 12,735 | 280178 | | | | | | | | | |
| | 264,784 | 12,7669 | 488983 | | | | | | | | | |
| | 264,296 | 12,4614 | 446017 | | | | | | | | | |
| | 264,653 | 13,2309 | 650735 | | | | | | | | | |
| | 264,069 | 13,3785 | 926610 | | | | | | | 335,586 | 22,7658 | 83647,5 |
| | 264,29 | 13,1021 | 265665 | | | | | | | | | |
| | 264,55 | 13,0155 | 501469 | | | | | | | | | |
| | 264,726 | 13,4997 | 391903 | | | | | | | 331,792 | 18,8759 | 53282,7 |
| | 264,574 | 13,2107 | 536034 | | | | | | | | | |
| | 264,266 | 13,0635 | 597931 | | | | | | | 336,014 | 23,391 | 86682,4 |
| | 264,325 | 12,5049 | 338954 | | | | | | | | | |
| | 264,773 | 11,3951 | 382211 | | | | | | | 335,265 | 25,5524 | 101110 |
| | 264,722 | 13,9044 | 516973 | | | | | | | | | |
| | 264,305 | 13,0834 | 547521 | | | | | | | | | |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 265,412 | 12,7868 | 310121 | | | | | | | |
| | 264,946 | 13,2371 | 487300 | | | | | 335,141 | 15,6045 | 32498,3 |
| | 264,749 | 10,9894 | 236232 | | | | | | | |
| | 264,954 | 14,1911 | 359981 | | | | | | | |
| | 264,503 | 12,5568 | 724732 | | | | | | | |
| | 264,526 | 12,1684 | 320446 | | 292,946 | 14,215 | 90829 | | | |
| | 264,223 | 12,6456 | 595628 | | | | | 335,476 | 23,215 | 137914 |
| | 264,394 | 13,542 | 764248 | | | | | 333,614 | 19,3198 | 69031,4 |
| | 264,89 | 12,7378 | 371506 | | | | | | | |
| | 264,07 | 13,2508 | 549271 | | | | | 337,157 | 15,1413 | 33546,3 |
| | 264,34 | 13,5641 | 839266 | | | | | 332,593 | 24,1487 | 75584,9 |
| | 264,5 | 12,1883 | 351084 | | | | | 334,411 | 26,4247 | 96109,6 |
| 48568,7 | 264,186 | 12,415 | 479179 | | | | | 326,506 | 19,4612 | 208675 |
| | 264,328 | 13,0695 | 694401 | | | | | 334,791 | 25,7842 | 105643 |
| | 264,922 | 12,8448 | 382987 | | | | | 338,234 | 20,3795 | 46184 |
| | 264,559 | 13,6816 | 646670 | | | | | 333,296 | 27,2531 | 79429,7 |
| | 266,186 | 12,8096 | 350332 | | | | | 337,151 | 28,9479 | 247986 |
| | 265,674 | 12,9506 | 370852 | | | | | 335,314 | 25,3101 | 259184 |
| | 265,81 | 13,3503 | 339323 | | | | | 335,367 | 27,0433 | 211627 |
| | 265,846 | 13,5259 | 423862 | | | | | 335,523 | 25,0583 | 245515 |
| | 265,219 | 13,7703 | 785347 | | | | | 335,858 | 24,8548 | 182859 |
| | 265,602 | 12,6034 | 273982 | | | | | 337,415 | 24,1366 | 174093 |
| | 265,563 | 13,3521 | 525588 | | | | | 335,859 | 25,548 | 264846 |
| | 265,839 | 13,9439 | 491489 | | | | | 336,224 | 27,6572 | 269469 |
| | 265,956 | 12,4966 | 399185 | | | | | 335,357 | 23,4098 | 233928 |
| | 265,655 | 12,6491 | 382407 | | | | | 336,075 | 28,2393 | 208873 |
| | 265,76 | 13,4369 | 431163 | | | | | 336,229 | 26,9248 | 218878 |
| | 266,271 | 12,497 | 301748 | | | | | 334,812 | 24,2735 | 243409 |
| | 265,734 | 11,9221 | 267020 | | | | | 336,193 | 27,8559 | 269824 |
| | 265,693 | 13,6664 | 361710 | | | | | 335,342 | 28,0491 | 238443 |
| | 265,727 | 11,5064 | 321202 | | | | | 336,451 | 25,9432 | 187618 |
| | 265,892 | 12,8097 | 402441 | | | | | 335,777 | 25,5413 | 232074 |
| | 265,912 | 13,554 | 285277 | | | | | 336,668 | 24,6039 | 186904 |
| | 265,669 | 13,7905 | 636733 | | | | | 336,652 | 22,1745 | 266627 |
| | 265,661 | 14,3544 | 526592 | | | | | 336,416 | 22,4907 | 181429 |
| | 263,821 | 15,9306 | 2,28E+06 | | | | | | | |
| | 262,729 | 13,5881 | 2,08E+06 | | 274,084 | 28,9776 | 532500 | | | |
| | 262,774 | 15,8782 | 3,29E+06 | | | | | | | |
| | 262,579 | 15,9885 | 2,49454+6 | | 286,172 | 20,2367 | 377134 | 332,733 | 19,0847 | 216538 |
| | 262,952 | 14,9529 | 1,85E+06 | | 286,353 | 19,5884 | 395927 | 332,757 | 18,1749 | 248056 |
| | 262,65 | 16,54 | 2,03E+06 | | 286,245 | 21,3008 | 435190 | 333,012 | 16,7325 | 136516 |
| | 263,279 | 14,9117 | 2,55E+06 | | | | | | | |
| | 262,744 | 14,4939 | 2,55E+06 | | | | | | | |
| | 263,197 | 15,9327 | 3,13E+06 | | | | | | | |
| | 263,274 | 15,7649 | 2,68E+06 | | | | | 333,617 | 19,9779 | 294221 |
| | 262,897 | 16,4839 | 2,74E+06 | | 287,632 | 19,6602 | 494171 | 331,476 | 10,9017 | 97301,6 |
| | 263,149 | 15,3097 | 2,79E+06 | | | | | | | |
| | 263,128 | 14,2941 | 2,53E+06 | | 291,64 | 12,0634 | 462634 | 328,807 | 14,827 | 157344 |
| | 262,97 | 15,6462 | 3,07E+06 | | | | | | | |
| | 263,169 | 16,4352 | 2,50E+06 | | | | | | | |
| | 263,725 | 14,4813 | 2,46E+06 | | 289,293 | 16,0648 | 548490 | | | |
| | 262,942 | 16,8703 | 2,93E+06 | | 287,279 | 18,5794 | 386701 | 331,448 | 9,02867 | 70404,7 |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 262,837 | 15,1142 | 2,79E+06 | | 275,359 | 30,8961 | 598696 | 332,198 | 15,2752 | 144795 |
| | 263,772 | 14,6592 | 3,39E+06 | | | | | | | |
| | 263,398 | 15,502 | 3,00E+06 | | | | | | | |
| | 263,373 | 14,4515 | 1,47E+06 | | 286,692 | 18,9246 | 261584 | | | |
| | 263,824 | 15,5917 | 2,21E+06 | | | | | | | |
| | 263,112 | 16,0175 | 3,76E+06 | | | | | 333,231 | 14,9565 | 164459 |
| | 263,255 | 15,8953 | 3,51E+06 | | | | | | | |
| | 263,556 | 14,1321 | 1,94E+06 | | 283,681 | 19,0219 | 534597 | | | |
| | 263,418 | 15,1449 | 3,51E+06 | | | | | | | |
| | 263,232 | 15,0221 | 172177 | | 287,949 | 14,6095 | 37767 | | | |
| | 263,798 | 15,1178 | 266701 | | | | | 336,347 | 12,5235 | 24524,3 |
| | 263,925 | 14,6055 | 273386 | | | | | 332,371 | 22,5262 | 58652,1 |
| | 263,919 | 13,2795 | 230520 | | | | | | | |
| | 263,315 | 14,1314 | 522214 | | | | | | | |
| | 263,447 | 12,6128 | 172026 | | | | | | | |
| | 263,909 | 14,0567 | 312410 | | | | | 333,159 | 19,8767 | 46013,4 |
| | 263,453 | 15,7487 | 494501 | | 289,339 | 12,7638 | 100002 | 331,463 | 12,0149 | 33576,1 |
| | 263,738 | 14,4997 | 703119 | | | | | | | |
| | 263,136 | 14,6422 | 543012 | | 283,629 | 17,3276 | 112931 | 331,812 | 23,9132 | 90593,2 |
| | 263,122 | 15,0842 | 510284 | | | | | | | |
| | 263,45 | 12,9922 | 417006 | | | | | | | |
| | 262,987 | 14,0406 | 559386 | | | | | | | |
| | 263,361 | 14,9016 | 718062 | | | | | | | |
| | 263,774 | 15,183 | 669074 | | | | | | | |
| | 264,458 | 14,574 | 715312 | | | | | | | |
| | 264,263 | 15,1154 | 662148 | | | | | | | |
| | 263,919 | 15,1199 | 742464 | | | | | | | |
| | 264,633 | 14,1726 | 645059 | | | | | | | |
| | 264,382 | 16,0441 | 564164 | | | | | | | |
| | 264,485 | 15,808 | 554264 | | | | | | | |
| | 264,599 | 14,8232 | 643892 | | | | | | | |
| | 264,916 | 14,733 | 583092 | | | | | | | |
| | 264,111 | 14,5708 | 624860 | | | | | | | |
| | 263,976 | 15,1372 | 756067 | | | | | | | |
| | 264,502 | 14,4467 | 498153 | | | | | | | |
| | 264,831 | 14,8868 | 625051 | | | | | | | |
| | 264,363 | 14,007 | 526961 | | | | | | | |
| | 264,392 | 15,9305 | 696922 | | | | | | | |
| | 264,981 | 14,5628 | 446348 | | | | | | | |
| | 263,186 | 15,2099 | 690121 | | | | | | | |
| | 263,584 | 14,1231 | 451165 | | | | | 336,101 | 28,9858 | 224281 |
| | 263,614 | 15,0805 | 723185 | | | | | | | |
| | 264,288 | 15,0713 | 624633 | | | | | 335,522 | 18,797 | 82131,2 |
| | 264,184 | 15,0934 | 737911 | | | | | | | |
| | 264,087 | 14,9721 | 468880 | | | | | 335,938 | 26,5568 | 187407 |
| | 264,353 | 13,9734 | 523318 | | | | | | | |
| | 263,911 | 14,7742 | 631188 | | | | | | | |
| | 264,133 | 14,8852 | 604493 | | | | | | | |
| | 264,134 | 15,0457 | 599808 | | | | | | | |
| | 264,727 | 15,4245 | 485930 | | | | | | | |
| | 263,871 | 15,6302 | 736114 | | | | | | | |
| | 263,871 | 15,63 | 736182 | | | | | | | |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 264,359 | 14,84 | 632640 | | | | | | |
| | 264,702 | 14,4468 | 535243 | | | | | | |
| | 264,318 | 15,3557 | 514133 | | | | 333,697 | 18,8017 | 81240,4 |
| | 263,515 | 19,091 | 337012 | | 292,009 | 10,9952 | 82233,4 | 332,379 | 15,3212 | 61402,2 |
| | 263,528 | 19,2049 | 349375 | | 292,052 | 11,1602 | 96529,1 | 332,195 | 15,8242 | 64732 |
| | 264,621 | 14,7725 | 512857 | | | | | 334,654 | 21,1887 | 166268 |
| | 264,533 | 15,8714 | 336414 | | | | | | | |
| | 264,121 | 15,2076 | 576902 | | | | | | | |
| | 265,261 | 13,7935 | 367250 | | | | | 335,847 | 29,5284 | 275650 |
| | 265,291 | 14,2319 | 430196 | | | | | 336,798 | 29,8178 | 228455 |
| | 265,383 | 13,201 | 347271 | | | | | 336,761 | 25,5609 | 181126 |
| | 265,194 | 12,5667 | 357824 | | | | | 336,003 | 25,0681 | 171668 |
| | 265,337 | 14,6894 | 353894 | | | | | 333,777 | 22,4846 | 156166 |
| | 265,417 | 14,8149 | 498018 | | | | | 334,923 | 25,4455 | 206694 |
| | 265,215 | 14,6254 | 362782 | | | | | 336,12 | 26,9985 | 247874 |
| | 265,81 | 14,865 | 347518 | | | | | 336,92 | 28,2517 | 246593 |
| | 265,804 | 13,2903 | 250143 | | | | | 338,078 | 29,6671 | 388921 |
| | 265,428 | 14,6037 | 416761 | | | | | 335,508 | 27,6364 | 203908 |
| | 265,223 | 13,4252 | 443038 | | | | | 337,687 | 27,2741 | 146893 |
| | 265,745 | 14,3055 | 326492 | | | | | 337,296 | 28,7692 | 270035 |
| | 265,573 | 14,3836 | 394499 | | | | | 336,621 | 29,048 | 315875 |
| | 265,079 | 14,8503 | 485980 | | | | | 338,391 | 33,0761 | 327495 |
| | 265,136 | 14,2134 | 497559 | | | | | 335,681 | 29,8789 | 324906 |
| | 265,538 | 13,7774 | 404167 | | | | | 335,68 | 25,3994 | 238242 |
| | 265,208 | 13,8146 | 427687 | | | | | 336,032 | 25,28 | 190854 |
| | 265,158 | 14,2746 | 459275 | | | | | 335,493 | 28,2154 | 267989 |
| | 264,102 | 13,2507 | 296954 | | | | | | | |
| | 261,138 | 18,801 | 865957 | | | | | | | |
| | 262,516 | 13,9018 | 320697 | | | | | | | |
| | 262,541 | 14,3652 | 1,86E+06 | | | | | | | |
| | 263,545 | 14,018 | 1,54E+06 | | | | | | | |
| | 263,65 | 13,8108 | 1,94E+06 | | | | | | | |
| | 264,072 | 14,0012 | 1,78E+06 | | | | | | | |
| | 263,748 | 13,4748 | 508709 | | | | | | | |
| | 263,478 | 13,4887 | 479977 | | | | | | | |
| | 263,602 | 14,003 | 279302 | | | | | | | |
| | 264,231 | 13,2718 | 397422 | | | | | | | |
| | 264,023 | 13,6773 | 327641 | | | | | | | |
| | 263,801 | 13,4623 | 425099 | | | | | | | |
| | 264,047 | 13,3957 | 463603 | | | | | | | |
| | 263,574 | 12,3827 | 435576 | | | | | | | |
| | 264,823 | 13,4297 | 616335 | | | | | | | |
| | 262,761 | 15,2648 | 780756 | | | | | | | |
| | 264,794 | 13,6474 | 608281 | | | | | | | |
| | 263,641 | 14,0036 | 579100 | | | | | | | |
| | 264,065 | 13,601 | 571053 | | | | | | | |
| | 264,444 | 14,4523 | 446146 | | | | | | | |
| | 264,906 | 13,177 | 558117 | | | | | | | |

Appendix III - Supplementary Table 3. *Cont.*

| Centre | Width | Area | Centre | Width | Area | Centre | Width | Area | Centre | Width | Area | Centre |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 355,889 | 3,49353 | 51915 | | | | | | | | | | 409,509 |
| 355,914 | 4,52351 | 176453 | | | | | | | 399,728 | 16,896 | 346458 | |
| 355,411 | 4,31725 | 181407 | | | | 393,751 | 5,34719 | 203710 | 401,916 | 7,80401 | 214042 | |
| 355,695 | 5,04445 | 143014 | | | | 393,846 | 4,33454 | 31420,4 | 400,444 | 19,361 | 427124 | |
| 355,488 | 5,13557 | 434421 | | | | 394,07 | 4,98878 | 140382 | 402,148 | 6,66006 | 154726 | |
| 355,955 | 5,10676 | 443393 | | | | 394,665 | 6,74515 | 167368 | 402,462 | 6,0507 | 105429 | |
| 355,965 | 5,02415 | 274322 | | | | 394,41 | 4,98655 | 110460 | 401,873 | 8,66913 | 154587 | |
| 355,942 | 4,50716 | 92218,9 | | | | | | | 405,597 | 26,6549 | 519066 | |
| 356,07 | 4,38841 | 180108 | | | | 397,829 | 12,0513 | 350156 | | | | |
| 356,041 | 4,76587 | 175787 | | | | | | | 401,39 | 19,3673 | 390103 | |
| | | | | | | | | | | | | |
| 355,81 | 2,96101 | 37020,6 | | | | | | | | | | |
| 355,89 | 4,56834 | 258829 | | | | | | | 399,444 | 18,7382 | 468033 | |
| 355,753 | 5,17038 | 653831 | | | | 394,246 | 4,72609 | 262724 | 402,25 | 4,98703 | 114101 | |
| 355,535 | 5,48499 | 304636 | | | | 393,981 | 5,58235 | 137555 | 402,416 | 7,51174 | 178929 | |
| 355,871 | 5,12673 | 231191 | | | | 394,561 | 7,1528 | 228967 | 402,841 | 7,70912 | 171210 | |
| 355,903 | 4,75401 | 245188 | | | | 394,137 | 3,83197 | 56814,2 | 400,036 | 13,2033 | 243706 | |
| 356,218 | 5,03573 | 93428,8 | | | | | | | 398,604 | 29,7799 | 2,35E+06 | |
| 356,131 | 4,71558 | 214193 | | | | | | | 398,432 | 19,8882 | 670852 | |
| 355,965 | 5,41636 | 244343 | | | | 396,68 | 18,6402 | 940376 | | | | |
| 356,034 | 5,40554 | 159496 | | | | | | | 398,235 | 18,1789 | 480381 | |
| 356,066 | 4,94383 | 64459,5 | | | | | | | 398,233 | 25,8332 | 1,03E+06 | |
| 356,019 | 5,25519 | 203533 | | | | 393,56 | 10,1019 | 364546 | 401,465 | 11,7928 | 312464 | |
| 356,069 | 5,01472 | 149714 | | | | 393,998 | 7,95347 | 306508 | 402,293 | 10,7703 | 229659 | |
| 356,621 | 5,07934 | 38240,1 | | | | | | | 398,294 | 14,0625 | 98100,7 | |
| 356,58 | 5,58166 | 84886,2 | | | | 396,455 | 7,441 | 36669,4 | 404,104 | 4,8689 | 21975,2 | |
| | | | | | | | | | | | | |
| 356,816 | 5,39939 | 52559,8 | | | | | | | 398,948 | 14,2742 | 63045 | |
| 356,732 | 6,1443 | 79549,1 | | | | | | | 398,489 | 12,6555 | 53819,2 | |
| 356,579 | 6,15047 | 79752,6 | | | | | | | 398,822 | 11,7422 | 49255,1 | |
| 356,251 | 11,5599 | 95143,1 | | | | | | | 398,822 | 16,4678 | 74210,6 | |
| | | | | | | | | | 398,103 | 21,9506 | 185455 | |
| 356,155 | 3,71682 | 25117,1 | | | | | | | 398,567 | 20,1211 | 149482 | |
| 356,805 | 5,24432 | 29782,5 | | | | | | | 399,138 | 15,254 | 76595,8 | |
| 356,859 | 4,57764 | 25892,2 | | | | | | | 397,618 | 18,8559 | 179948 | |
| 356,723 | 5,54879 | 32906,3 | | | | | | | 398,239 | 17,8153 | 110764 | |
| 356,093 | 10,5524 | 84308,4 | | | | | | | 397,888 | 14,2322 | 92659,9 | |
| 356,933 | 4,73663 | 29281,7 | | | | | | | 397,227 | 17,7144 | 128528 | |
| 357,199 | 5,7023 | 64735,6 | | | | | | | 398,354 | 14,6096 | 87278,6 | |
| 356,659 | 5,32206 | 73822,2 | | | | | | | 397,952 | 13,2134 | 60907,7 | |
| 356,346 | 6,56266 | 42665,8 | | | | | | | 399,422 | 14,6777 | 54365,5 | |
| 357,529 | 4,861 | 24014,8 | | | | | | | 403,83 | 22,1886 | 99741 | |
| 356,679 | 7,84245 | 138169 | | | | 395,039 | 9,08374 | 90315,5 | 403,241 | 5,89657 | 26226,4 | |
| 356,563 | 4,99627 | 55929,7 | | | | | | | 397,164 | 11,7298 | 58123,9 | |
| 356,638 | 4,62176 | 28214 | | | | | | | 398,969 | 18,601 | 105262 | |
| 356,718 | 5,04061 | 38008,3 | | | | | | | 398,871 | 15,3735 | 77804,2 | |
| 356,711 | 3,74527 | 26984,7 | | | | | | | 398,205 | 16,0815 | 99503,5 | |
| 356,92 | 5,58297 | 45575,1 | | | | | | | | | | |
| 356,728 | 6,09629 | 117087 | | | | | | | 396,537 | 12,5416 | 82210,6 | |
| 357,022 | 4,95143 | 27140,1 | | | | | | | 397,657 | 15,5597 | 115158 | |
| 356,68 | 5,359 | 47593,1 | | | | | | | 398,877 | 17,1759 | 122034 | |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 357,035 | 4,83082 | 19112 | | | | | | | 396,195 | 19,1009 | 227504 | |
| 356,834 | 5,1544 | 40977,3 | | | | | | | 399,199 | 15,067 | 76656,7 | |
| | | | | | | 395,022 | 22,0755 | 799633 | | | | |
| 356,962 | 5,13838 | 27503,9 | | | | | | | 396,42 | 22,9779 | 756228 | |
| 356,543 | 5,24531 | 62974,5 | | | | | | | 400,399 | 15,0546 | 55763,2 | |
| 357,051 | 5,45727 | 58635,1 | | | | | | | 401,655 | 17,0169 | 92184,5 | |
| 357,029 | 5,82307 | 42418,3 | | | | | | | 398,705 | 12,9674 | 82831,7 | |
| 357,251 | 3,74974 | 17207,3 | | | | | | | 403,103 | 22,9325 | 84996,4 | |
| 356,432 | 5,0904 | 69015,8 | | | | 393,754 | 22,6746 | 24895 | 401,758 | 11,2894 | 54292,9 | |
| 356,935 | 4,7608 | 29787,6 | | | | | | | 399,411 | 13,6182 | 71188,8 | |
| 357,245 | 4,90393 | 25450,1 | | | | | | | 404,587 | 24,3554 | 89589,3 | |
| 356,659 | 5,35908 | 69169 | | | | 396,415 | 14,2266 | 82153,9 | | | | |
| 356,418 | 5,92292 | 68158,6 | 368,338 | 11,9132 | 85862,1 | | | | 399,296 | 19,5339 | 139363 | |
| 356,799 | 4,52891 | 23632,6 | | | | | | | 398,235 | 15,0278 | 93213,6 | |
| 356,672 | 4,91375 | 49533,4 | | | | | | | 397,596 | 14,195 | 75639,6 | |
| 356,647 | 5,94936 | 24000,4 | | | | | | | 399,149 | 14,6049 | 48520 | |
| | | | | | | 396,721 | 14,9408 | 113919 | | | | |
| | | | | | | 396,235 | 16,0869 | 96193,6 | | | | |
| 357,56 | 5,25614 | 24521,9 | | | | 396,544 | 16,9973 | 150540 | | | | |
| 357,527 | 5,80503 | 38119,7 | | | | 395,611 | 15,001 | 90503,5 | | | | |
| | | | | | | 396,959 | 15,6631 | 91641,8 | | | | |
| 357,687 | 4,91545 | 28449,8 | | | | 396,886 | 15,0231 | 103871 | | | | |
| 358 | 4,83318 | 32751,4 | | | | 396,447 | 14,5027 | 97162 | | | | |
| 357,536 | 5,73723 | 32837,7 | | | | 395,891 | 18,8113 | 321571 | | | | |
| 358,028 | 4,07532 | 18810,9 | | | | 396,797 | 18,1548 | 205137 | | | | |
| | | | | | | 395,515 | 18,2624 | 250309 | | | | |
| | | | | | | 396,055 | 19,611 | 475932 | | | | |
| 357,666 | 6,37816 | 79239,4 | | | | 395,264 | 16,1052 | 118508 | | | | |
| 359,147 | 20,2535 | 213502 | | | | 395,368 | 21,359 | 343919 | | | | |
| 357,74 | 6,50294 | 49231,7 | | | | 394,929 | 17,7274 | 102631 | | | | |
| 357,111 | 5,37095 | 52818,5 | | | | 396,153 | 12,0458 | 70962 | | | | |
| 357,035 | 4,30099 | 34961,2 | | | | 396,153 | 18,0691 | 230698 | | | | |
| 357,59 | 5,61324 | 2263,7 | | | | 395,704 | 14,4761 | 95105,3 | | | | |
| 358,066 | 4,65532 | 23029,6 | | | | 396,469 | 13,537 | 106416 | | | | |
| 358,081 | 4,75838 | 23913,4 | | | | 397,58 | 14,4219 | 81860,7 | | | | |
| | | | | | | 395,378 | 28,9054 | 6,23E+06 | | | | |
| 355,756 | 5,57802 | 151514 | 383,412 | 6,74617 | 24273 | 394,628 | 4,79157 | 41998,1 | 399,217 | 19,0038 | 532500 | |
| 356,334 | 4,8066 | 48154,2 | | | | 396,102 | 26,7119 | 1,53E+06 | | | | |
| | | | | | | | | | 398,55 | 25,837 | 791370 | |
| | | | | | | 395,795 | 23,7574 | 1,56E+06 | | | | |
| | | | | | | | | | 398,674 | 25,1461 | 473197 | |
| | | | | | | 396,429 | 23,611 | 1,51E+06 | | | | |
| | | | | | | 395,63 | 28,3018 | 5,35E+06 | | | | |
| | | | | | | 395,47 | 25,5513 | 2,15E+06 | | | | |
| | | | | | | | | | 399,646 | 27,6822 | 1,31E+06 | |
| | | | | | | | | | 398,749 | 33,5691 | 1,39E+06 | |
| 356,791 | 4,86017 | 56945,7 | | | | | | | 397,183 | 20,5013 | 538158 | |
| 356,605 | 4,88473 | 93150,3 | | | | | | | 402,264 | 23,1848 | 887277 | |
| | | | | | | 397,082 | 28,811 | 1,94E+06 | | | | |
| | | | | | | 396,143 | 28,665 | 2,80E+06 | | | | |
| 356,193 | 5,41441 | 201089 | | | | | | | 398,937 | 18,6546 | 615198 | |
| | | | | | | 397,643 | 31,0336 | 1,70E+06 | | | | |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 404,634 | 38,9512 | 1,32E+06 | | |
| | | | | 397,018 | 28,9493 | 3,83E+06 | | | | |
| | | | | | | 404,587 | 44,4859 | 2,06607 | | |
| 356,192 | 5,4995 | 102988 | | 396,209 | 22,059 | 1,04E+06 | | | | |
| | | | | 395,37 | 29,0534 | 6,07E+06 | | | | |
| | | | | 396,515 | 27,4164 | 2,07E+06 | | | | |
| 356,097 | 5,51839 | 111966 | | 397,606 | 24,7608 | 800824 | | | | |
| | | | | 398,139 | 27,4118 | 1,15E+06 | | | | |
| | | | | 396,183 | 24,8303 | 189823 | | | | |
| | | | | 398,771 | 20,2741 | 53332,8 | | | | |
| | | | | 395,311 | 21,9236 | 192143 | | | | |
| | | | | 395,593 | 20,9421 | 211213 | | | | |
| | | | | 395,474 | 17,1567 | 60449,2 | | | | |
| | | | | 398,174 | 25,352 | 151270 | | | | |
| | | | | 397,558 | 24,5831 | 242338 | | | | |
| | | | | | | 401,946 | 23,0556 | 95987,9 | | |
| | | | | | | 398,588 | 17,3042 | 69531,4 | | |
| | | | | 395,739 | 19951 | 528944 | | | | |
| 355,375 | 4,51118 | 33733,2 | | 395,772 | 20,6283 | 237081 | | | | |
| | | | | | | 398,275 | 27,2164 | 399039 | | |
| | | | | 396,14 | 24,6953 | 311739 | | | | |
| | | | | 397,911 | 19,0289 | 122542 | | | | |
| | | | | 397,88 | 23,3038 | 257571 | | | | |
| | | | | 397,562 | 22,4799 | 206460 | | | | |
| | | | | 397,261 | 21,8096 | 193652 | | | | |
| | | | | 397,154 | 20,1485 | 387117 | | | | |
| | | | | 396,586 | 20,4397 | 314623 | | | | |
| | | | | 396,314 | 22,0991 | 431727 | | | | |
| | | | | 397,201 | 16,0867 | 178456 | | | | |
| | | | | 396,746 | 17,848 | 221760 | | | | |
| | | | | 396,931 | 20,1091 | 182898 | | | | |
| | | | | 399,728 | 26,5095 | 213151 | | | | |
| | | | | 396,256 | 21,488 | 309343 | | | | |
| | | | | 399,061 | 16,6951 | 108630 | | | | |
| | | | | 397,518 | 21,1519 | 390510 | | | | |
| | | | | 395,87 | 18,8116 | 305970 | | | | |
| | | | | 395,911 | 25,5928 | 1,93E+06 | | | | |
| | | | | | | 396,514 | 20,6881 | 205712 | | |
| | | | | 395,069 | 18,6319 | 276505 | | | | |
| | | | | | | 400,529 | 30,1144 | 371872 | | |
| | | | | | | 395,914 | 21,9243 | 315328 | | |
| | | | | | | 397,809 | 23,4934 | 419105 | | |
| | | | | | | 396,931 | 13,1337 | 65627,3 | | |
| | | | | | | 396,572 | 21,8837 | 298028 | | |
| | | | | | | 396,081 | 18,6539 | 307692 | | |
| | | | | | | 396,395 | 22,9945 | 720527 | | |
| | | | | | | 396,396 | 22,8137 | 730427 | | |
| | | | | | | 397,408 | 19,6754 | 162203 | | |
| | | | | | | 398,343 | 24,7933 | 157194 | | |
| | | | | | | 398,354 | 24,8083 | 157115 | | |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 397,174 | 19,7997 | 212514 | |
| | | | | | | 397,237 | 18,258 | 200652 | |
| | | | | | | 397,532 | 23,1236 | 271802 | |
| | | | | | | 397,153 | 20,5563 | 202408 | |
| | | | | | | 397,239 | 20,4158 | 203576 | |
| | | | | | | 396,535 | 18,0669 | 156865 | |
| | | | | | | 396,081 | 24,0609 | 982022 | |
| | | | | | | 399,849 | 20,8636 | 117362 | |
| 358,019 | 5,47245 | 24418,7 | | 395,835 | 18,3784 | 159551 | | | | |
| | | | | 395,73 | 14,9803 | 62610 | | | | |
| 357,765 | 5,31791 | 46374,8 | | 394,959 | 17,2917 | 95724,6 | | | | |
| 357,277 | 5,74513 | 64256,5 | | 396,309 | 15,1245 | 100675 | | | | |
| | | | | 395,353 | 20,6927 | 676743 | | | | |
| | | | | 397,204 | 13,9218 | 117515 | | | | |
| | | | | 395,781 | 18,9553 | 293329 | | | | |
| | | | | 396,244 | 15,962 | 80838,9 | | | | |
| | | | | 396,874 | 21,0261 | 258920 | | | | |
| | | | | 394,798 | 17,6254 | 137969 | | | | |
| | | | | 396,475 | 17,0027 | 114519 | | | | |
| | | | | 394,774 | 15,8823 | 108678 | | | | |
| | | | | 394,94 | 16,7529 | 95802,6 | | | | |
| | | | | 395,023 | 18,0482 | 160625 | | | | |
| 357,961 | 7,62098 | 86528,8 | | 395,417 | 16,8253 | 170387 | | | | |
| 357,451 | 5,13354 | 35843,2 | | 396,535 | 16,8015 | 123308 | | | | |
| 357,97 | 5,15332 | 27400,4 | | 395,705 | 18,5925 | 157759 | | | | |
| | | | | | | | 403,694 | 37,76 | 326116 | |
| | | | | | | | | | | 408,588 |
| | | | 378,548 | 25,0236 | 215737 | | | | | 409,432 |
| 356,043 | 4,82973 | 18062,8 | | | | 395,249 | 32,4704 | 263025 | | |
| | | | | | | 392,425 | 30,4355 | 624175 | | 406,354 |
| | | | 376,421 | 10,2194 | 43432,5 | | | | | 406,262 |
| | | | | | | | 402,933 | 34,9653 | 293625 | |
| | | | | | | | | | | 409,151 |
| | | | | | | | | | | 408,376 |
| | | | | | | | 399,684 | 209536 | 62252,6 | |
| | | | | | | | | | | 410,253 |
| | | | | | | | | | | 406,153 |
| | | | | | | | 402,288 | 25,4082 | 112152 | |
| | | | | | | | | | | 407,85 |
| | | | | | | | 401,919 | 36,2563 | 270156 | |
| | | | | | | | | | | 404,079 |
| | | | | | | | | | | 408,927 |
| | | | | | | | | | | 405,395 |
| | | | | | | | | | | 406,068 |

Appendix III - Supplementary Table 3. *Cont.*

| Width | Area | Centre | Width | Area | Centre | Width | Area | Centre | Width | Area | Centre | Width |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31,9514 | 946554 | | | | | | | | | | 464,479 | 8,62327 |
| | | 415,68 | 3,9553 | 21742,8 | | | | | | | 464,682 | 8,89728 |
| | | 412,032 | 7,80401 | 99554,7 | | | | | | | 464,56 | 9,12906 |
| | | 415,935 | 0,315133 | 72879,9 | | | | | | | 464,738 | 9,07281 |
| | | | | | | | | | | | 464,913 | 8,83434 |
| | | | | | | | | | | | 465,002 | 8,9255 |
| | | | | | | | | | | | 465,223 | 9,00141 |
| | | | | | | | | | | | 464,982 | 8,97221 |
| | | 414,525 | 12,0513 | 194057 | | | | | | | 464,977 | 9,81016 |
| | | | | | | | | | | | 465,206 | 8,89985 |
| | | 413,778 | 47,1382 | 2,55E+06 | | | | | | | 464,719 | 10,0053 |
| | | 411,341 | 44,2076 | 1,96E+06 | | | | | | | 464,787 | 9,62975 |
| | | | | | | | | | | | 465,125 | 8,96922 |
| | | | | | | | | | | | 465,164 | 8,52029 |
| | | 412,565 | 9,81497 | 92705,4 | | | | | | | 464,918 | 8,89892 |
| | | 412,444 | 9,23122 | 78552,1 | | | | | | | 465,085 | 9,04868 |
| | | | | | | | | | | | 465,056 | 9,05219 |
| | | | | | | | | | | | 464,704 | 9,94781 |
| | | | | | | | | | | | 464,645 | 9,31386 |
| | | | | | | | | | | | 464,835 | 9,55204 |
| | | | | | | | | | | | 464,319 | 9,63952 |
| | | 417,159 | 7,32105 | 64726,6 | | | | | | | 464,588 | 9,93165 |
| | | | | | | | | | | | 464,978 | 9,40589 |
| | | 413,494 | 8,28161 | 55037,3 | | | | | | | 464,945 | 9,31457 |
| | | | | | | | | | | | 465,723 | 9,8279 |
| | | | | | | | | | | | 465,993 | 9,31123 |
| | | | | | | | | | | | 465,819 | 9,5294 |
| | | | | | | | | | | | 465,996 | 9,49659 |
| | | | | | | | | | | | 465,94 | 9,25714 |
| | | | | | | | | | | | 465,826 | 9,57434 |
| | | | | | | | | | | | 465,902 | 9,35867 |
| | | | | | | | | | | | 465,744 | 10,4713 |
| | | | | | | | | | | | 465,835 | 9,7227 |
| | | 414,915 | 8,08561 | 16259,8 | | | | | | | 465,54 | 10,3368 |
| | | 411,524 | 3,40319 | 28894,1 | | | | | | | 465,968 | 9,68822 |
| | | | | | | | | | | | 465,672 | 9,65639 |
| | | | | | | | | | | | 465,667 | 9,25352 |
| | | | | | | | | | | | 465,811 | 9,92538 |
| | | | | | | | | | | | 465,988 | 9,58306 |
| | | | | | | | | | | | 465,841 | 9,73749 |
| | | | | | | | | | | | 465,988 | 9,19026 |
| | | | | | | | | | | | 465,901 | 9,45372 |
| | | | | | | | | | | | 465,649 | 9,48915 |
| | | | | | | | | | | | 465,623 | 9,8657 |
| | | | | | | | | | | | 465,529 | 9,56521 |
| | | | | | | | | | | | 465,709 | 9,76732 |
| | | | | | | | | | | | 465,963 | 9,57098 |
| | | | | | | | | | | | 465,484 | 10,1432 |
| | | | | | | | | | | | 466,021 | 9,18216 |
| | | | | | | | | | | | 465,296 | 10,3977 |
| | | | | | | | | | | | 465,583 | 10,0747 |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | 465,876 | 10,3408 |
| | | | | | 465,701 | 10,2472 |
| | | | | | 465,417 | 10,3069 |
| | | | | | 465,659 | 9,772 |
| | | | | | 465,899 | 9,37688 |
| | | | | | 465,544 | 9,86933 |
| | | | | | 465,812 | 9,68059 |
| | | | | | 465,946 | 9,43789 |
| | | | | | 465,914 | 9,95013 |
| | | | | | 465,372 | 10,0983 |
| | | | | | 466,149 | 9,25376 |
| | | | | | 465,726 | 9,71185 |
| | | | | | 465,711 | 9,80136 |
| | | | | | 465,827 | 9,45926 |
| | | | | | 465,798 | 9,59705 |
| | | | | | 465,456 | 9,79717 |
| | | | | | 465,979 | 9,84981 |
| | | | | | 465,846 | 11,1683 |
| | | | | | 465,872 | 10,1144 |
| | | | | | 465,55 | 10,6115 |
| | | | | | 465,801 | 10,228 |
| | | | | | 465,659 | 10,5326 |
| | | | | | 465,93 | 9,49574 |
| | | | | | 465,738 | 9,67809 |
| | | | | | 466,191 | 10,1291 |
| | | | | | 466,016 | 10,1615 |
| | | | | | 465,878 | 10,8145 |
| | | | | | 465,958 | 9,85783 |
| | | | | | 465,975 | 9,5005 |
| | | | | | 465,872 | 9,66967 |
| | | | | | 465,864 | 9,67719 |
| | | | | | 465,942 | 10,0497 |
| | | | | | 465,836 | 10,0649 |
| | | | | | 466 | 9,55227 |
| | | | | | 465,811 | 10,4932 |
| | | | | | 463,587 | 10,9631 |
| | | | | | 463,401 | 11,1777 |
| | | | | | 462,975 | 12,5986 |
| | | 436,269 | 41,5968 | 2,58E+06 | 462,778 | 12,122 |
| | | | | | 462,86 | 11,6857 |
| | | | | | 462,564 | 13,273 |
| | | | | | 463,335 | 12,2357 |
| | | | | | 462,836 | 12,3969 |
| | | | | | 462,829 | 12,4273 |
| | | | | | 462,784 | 14,2141 |
| | | | | | 463,182 | 11,8856 |
| | | | | | 463,246 | 11,9426 |
| | | 434,187 | 45,2047 | 1,41E+06 | 463,634 | 11,8134 |
| | | | | | 462,976 | 12,9354 |
| | | | | | 463,012 | 11,1541 |
| | | | | | 464,216 | 10,5454 |
| | | | | | 463,166 | 11,5633 |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | 463,535 | 11,8711 |
| | | | | | | 463,806 | 9,68871 |
| | | | | | | 463,317 | 12,5046 |
| | | | | | | 463,459 | 11,0581 |
| | | | | | | 463,591 | 10,9631 |
| | | 423,446 | 61,107 | 3,54E+06 | | 462,984 | 14,7846 |
| | | 437,306 | 40,0207 | 2,07E+06 | | 463,434 | 11,5886 |
| | | | | | | 464,064 | 10,0988 |
| | | | | | | 463,54 | 11,4696 |
| | | | | | | 464,52 | 10,4475 |
| | | | | | | 463,61 | 9,23315 |
| | | | | | | 463,674 | 9,64856 |
| | | | | | | 463,927 | 11,0844 |
| | | | | | | 463,834 | 10,1056 |
| | | | | | | 464,219 | 9,53409 |
| | | 445,137 | 38,1169 | 471526 | | 464,015 | 9,75338 |
| | | | | | | 463,673 | 10,6371 |
| | | | | | | 464,143 | 10,0131 |
| | | | | | | 463,414 | 10,0542 |
| | | 448,045 | 37,5322 | 208158 | | 463,93 | 9,81997 |
| | | | | | | 464,016 | 10,1102 |
| | | | | | | 463,368 | 11,3994 |
| | | | | | | 464,026 | 10,2334 |
| | | | | | | 463,243 | 14,9177 |
| | | | | | | 464,9 | 11,1144 |
| | | | | | | 464,713 | 11,4137 |
| | | | | | | 464,59 | 11,1396 |
| | | | | | | 464,24 | 13,7022 |
| | | | | | | 464,456 | 12,3675 |
| | | | | | | 464,263 | 12,5286 |
| | | | | | | 464,688 | 12,3324 |
| | | | | | | 464,062 | 12,6936 |
| | | | | | | 464,463 | 11,831 |
| | | | | | | 464,427 | 11,9918 |
| | | | | | | 464,392 | 12,2897 |
| | | | | | | 464,286 | 11,2842 |
| | | 444,545 | 34,5268 | 558453 | | 464,741 | 10,9253 |
| | | | | | | 464,1 | 12,5539 |
| | | | | | | 465,402 | 11,0983 |
| | | | | | | 463,832 | 12,8257 |
| | | | | | | 463,544 | 12,1457 |
| | | | | | | 463,896 | 11,1186 |
| | | | | | | 464,216 | 13,725 |
| | | | | | | 464,629 | 11,3426 |
| | | | | | | 464,085 | 11,9751 |
| | | | | | | 464,508 | 11,689 |
| | | | | | | 463,086 | 13,1535 |
| | | | | | | 464,887 | 11,5215 |
| | | | | | | 464,882 | 11,4625 |
| | | | | | | 464,685 | 11,1793 |
| | | 431,654 | 49,1742 | 241655 | | 464,626 | 13,1883 |
| | | 431,847 | 49,5397 | 244466 | | 464,634 | 13,2286 |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 464,958 | 12,107 |
| | | | | | | | | | | 464,514 | 13,695 |
| | | | | | | | | | | 464,917 | 11,6239 |
| | | | | | | | | | | 464,159 | 12,121 |
| | | | | | | | | | | 464,129 | 12,6619 |
| | | | | | | | | | | 463,828 | 14,0743 |
| | | | | | | | | | | 464,135 | 10,2795 |
| | | | | | 439,292 | 42,8162 | 968432 | | | 464,452 | 15,7025 |
| | | | | | 444,749 | 19,1645 | 81321,6 | | | 465,304 | 11,7653 |
| | | | | | | | | 453,742 | 35,991 | 170262 | 465,546 | 10,5907 |
| | | | | | | | | | | | 465,522 | 10,5374 |
| | | | | | | | | | | | 465,151 | 10,8099 |
| | | | | | | | | | | | 464,052 | 12,5086 |
| | | | | | | | | | | | 464,919 | 13,7998 |
| | | | | | | | | | | | 465,307 | 11,6487 |
| | | | | | | | | | | | 464,822 | 12,5947 |
| | | | | | | | | | | | 464,748 | 12,751 |
| | | | | | | | | | | | 465,284 | 11,6533 |
| | | | | | | | | | | | 465,46 | 12,9664 |
| | | | | | | | | | | | 464,892 | 15,188 |
| | | | | | | | | | | | 464,517 | 14,321 |
| | | | | | | | | | | | 464,866 | 12,6472 |
| | | | | | 448,521 | 31,9404 | 509787 | | | | 465,074 | 11,7181 |
| | | | | | | | | | | | 465,225 | 11,3288 |
| | | | | | | | | | | | 465,327 | 10,6731 |
| | | | | | | | | | | | 464,809 | 12,0987 |
| | | | | | | | | | | | | |
| | | | | | | | | | | | 464,284 | 8,33084 |
| 37,1431 | 119611 | | | | | | | | | | | |
| 31,6316 | 1,50E+06 | | | | | | | | | | 464,057 | 10,2562 |
| | | 412,729 | 22,5373 | 344399 | | | | | | | 464,609 | 8,78708 |
| 26,2933 | 890193 | | | | | | | | | | 464,388 | 8,98039 |
| 36,9721 | 1,35E+06 | | | | | | | | | | 464,615 | 9,98227 |
| | | | | | | | | | | | 464,474 | 10,6276 |
| 39,601 | 242090 | | | | | | | | | | 464,055 | 12,82 |
| 31,6812 | 116598 | | | | | | | | | | 463,854 | 8,44389 |
| | | 412,563 | 37,1739 | 237234 | | | | | | | 464,575 | 9,47502 |
| | | | | | | | | | | | 464,551 | 9,14715 |
| 35,6341 | 154099 | | | | | | | | | | 464,372 | 9,80142 |
| 37,3196 | 406816 | | | | | | | | | | 464,47 | 9,88845 |
| | | | | | | | | | | | 464,648 | 9,12042 |
| 46,6493 | 368197 | | | | | | | | | | 465,477 | 11,177 |
| | | 412,555 | 42,0783 | 139593 | | | | | | | 465,475 | 9,34829 |
| | | | | | | | | | | | 465,283 | 9,61069 |
| 45,4773 | 537680 | | | | | | | | | | | |
| 39,0578 | 477965 | | | | | | | | | | | |
| 33,4075 | 107047 | | | | | | | | | | 465,331 | 9,59011 |
| 40,3331 | 641282 | | | | | | | | | | | |

Appendix III - Supplementary Table 3. *Cont.*

| Area | | | | Centre | Width | Area | Centre | Width | Area | Centre | Width | Area |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3,32E+06 | | | | | | | | | | | | |
| 7,19E+06 | 477,065 | 13,3325 | 675987 | | | | 508,925 | 11,168 | 646611 | | | |
| 6,92E+06 | 478,082 | 11,7374 | 619575 | | | | | | | | | |
| 6,25E+06 | 477,576 | 11,3121 | 778257 | | | | 507,472 | 7,91711 | 577667 | | | |
| 1,07E+07 | | | | | | | | | | | | |
| 1,33E+07 | | | | | | | | | | | | |
| 1,19E+07 | | | | | | | 509,176 | 10,3621 | 566086 | | | |
| 4,74E+06 | | | | | | | | | | | | |
| 8,00E+06 | | | | | | | 509,873 | 12,5587 | 219308 | | | |
| 7,05E+06 | | | | | | | 509,494 | 11,2474 | 667868 | | | |
| 1,77E+06 | | | | | | | | | | | | |
| 3,02E+06 | | | | | | | | | | | | |
| 8,43E+06 | | | | | | | 509,573 | 10,2361 | 336333 | | | |
| 1,78E+07 | | | | | | | | | | | | |
| 8,97E+06 | | | | | | | 509,336 | 11,6823 | 182260 | | | |
| 9,35E+06 | | | | | | | 509,604 | 9,93471 | 301420 | | | |
| 1,03E+07 | | | | | | | | | | | | |
| 5,29E+06 | | | | | | | 509,775 | 3,76665 | 13239,7 | | | |
| 7,36E+06 | 476,18 | 12,8965 | 891407 | | | | | | | 510,971 | 12,9794 | 845727 |
| 1,04E+07 | | | | | | | | | | | | |
| 6,73E+06 | 474,054 | 14,3493 | 587523 | | | | | | | | | |
| 3,16E+06 | 478,704 | 10,1045 | 714837 | | | | 508,233 | 8,75707 | 714900 | | | |
| 1,04E+07 | | | | | | | | | | | | |
| 7,34E+06 | | | | | | | | | | 511,504 | 13,748 | 523553 |
| 2,01E+06 | | | | | | | | | | | | |
| 2,40E+06 | | | | | | | | | | | | |
| 662354 | | | | | | | | | | | | |
| 1,85E+06 | | | | | | | | | | | | |
| 1,99E+06 | | | | | | | | | | | | |
| 2,21E+06 | | | | | | | | | | | | |
| 1,36E+06 | | | | | | | | | | | | |
| 730319 | | | | | | | | | | | | |
| 1,10E+06 | | | | | | | | | | | | |
| 1,21E+06 | | | | | | | | | | 510,927 | 9,05095 | 32211,4 |
| 1,51E+06 | | | | | | | | | | | | |
| 1,20E+06 | 479,509 | 13,7717 | 171815 | | | | | | | | | |
| 2,29E+06 | 477,782 | 17,9658 | 266456 | | | | | | | | | |
| 1,61E+06 | | | | | | | | | | | | |
| 1,75E+06 | | | | | | | | | | | | |
| 1,85E+06 | | | | | | | | | | | | |
| 1,28E+06 | | | | | | | | | | | | |
| 1,08E+06 | | | | | | | | | | | | |
| 2,39E+06 | | | | | | | | | | | | |
| 1,81E+06 | | | | | | | | | | | | |
| 1,35E+06 | 478,522 | 13,628 | 156180 | | | | | | | 511,234 | 14,6632 | 289977 |
| 1,50E+06 | | | | | | | | | | | | |
| 1,50E+06 | | | | | | | | | | | | |
| 1,85E+06 | | | | | | | | | | | | |
| 2,71E+06 | | | | | | | | | | | | |
| 1,46E+06 | | | | | | | | | | | | |
| 1,37E+06 | | | | | | | | | | | | |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1,33E+06 | | | | | | | | | |
| 1,77E+06 | | | | | | | | | |
| 2,09E+06 | | | | | | | | | |
| 1,44E+06 | | | | | | | | | |
| 1,94E+06 | | | | | | | | | |
| 2,42E+06 | | | | | | | | | |
| 1,91E+06 | | | | | | | | | |
| 1,14E+06 | | | | | | | | | |
| 1,95E+06 | | | | | | | | | |
| 1,51E+06 | | | | | | | | | |
| 990412 | | | | | | | | | |
| 2,23E+06 | | | | | | | | | |
| 2,14E+06 | | | | | | | | | |
| 1,52E+06 | | | | | | | | | |
| 1,75E+06 | | | | | | | | | |
| 991567 | | | | | | | | | |
| 1,05E+06 | | | | | | | | | |
| 693782 | | | | | | | | | |
| 873414 | | | | | | | | | |
| 1,02E+06 | | | | | | | | | |
| 766664 | | | | | | | | | |
| 1,27E+06 | | | | | | | | | |
| 1,01E+06 | | | | | | | | | |
| 867301 | | | | | | | | | |
| 845189 | | | | | | | | | |
| 602042 | | | | | | | | | |
| 502795 | | | | | | | | | |
| 1,59E+06 | | | | | | | | | |
| 1,11E+06 | | | | | | | | | |
| 1,05E+06 | | | | | | | | | |
| 1,62E+06 | | | | | | | | | |
| 1,46E+06 | | | | | | | | | |
| 751356 | | | | | | | | | |
| 1,06E+06 | | | | | | | | | |
| 942943 | | | | | | | | | |
| 3,56E+06 | | | | | | | | 510,172 | 14,8883 | 1,41E+06 |
| 5,87E+06 | 476,053 | 10,4403 | 406015 | | 508,886 | 7,99887 | 141123 | | | |
| 2,93E+06 | | | | | | | | 510,095 | 13,651 | 411018 |
| 1,47E+06 | 476,134 | 8,69238 | 92501,6 | | 509,69 | 13,3209 | 419759 | | | |
| 1,86E+06 | 475,858 | 8,1921 | 129964 | | 509,241 | 13,7352 | 723607 | | | |
| 1,08E+06 | 477,026 | 8,1907 | 220173 | | 508,519 | 11,2447 | 436567 | | | |
| 4,99E+06 | | | | | | | | 510,702 | 12,3213 | 406808 |
| 2,96E+06 | | | | | | | | | | |
| 1,22E+06 | | | | | | | | 511,412 | 19,4684 | 1,11E+06 |
| 1,68E+06 | | | | | | | | | | |
| 1,03E+06 | 476,3 | 7,93874 | 129099 | | 509,353 | 12,6412 | 501231 | | | |
| 2,41E+06 | | | | | | | | | | |
| 6,56E+06 | | | | | | | | | | |
| 1,06E+06 | | | | | | | | 511,322 | 17,6728 | 734025 |
| 658188 | | | | | 509,915 | 16,836 | 1,18E+06 | | | |
| 8,28E+06 | | | | | | | | 510,08 | 11,3411 | 812262 |
| 943169 | 476,364 | 8,40452 | 126378 | | 509,899 | 14,9364 | 780838 | | | |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1,54E+06 | 476,576 | 6,99301 | 76053,7 | | 509,661 | 13,2497 | 414933 | | | | |
| 1,52E+06 | 474,614 | 10,6278 | 247278 | | 510,003 | 13,8981 | 789583 | | | | |
| 1,73E+06 | 477,165 | 6,81791 | 74523,1 | | 509,82 | 12,1396 | 277537 | | | | |
| 4,60E+06 | 476,321 | 12,2348 | 518419 | | 509,565 | 12,3017 | 488198 | | | | |
| 3,61E+06 | | | | | | | | | 510,224 | 15,1159 | 1,45E+06 |
| 856153 | | | | | | | | | 511,383 | 14,0602 | 230737 |
| 3,19E+06 | | | | | | | | | 511,509 | 14,8862 | 606711 |
| 3,55E+06 | 475,594 | 11,567 | 378259 | | | | | | | | |
| 1,70E+06 | | | | | | | | | | | |
| 82305,1 | 478,471 | 8,21973 | 52357,6 | | 508,421 | 10,8232 | 115638 | | | | |
| 238062 | | | | | | | | | | | |
| 138374 | | | | | | | | | | | |
| 233170 | | | | | | | | | | | |
| 214363 | | | | | | | | | | | |
| 624219 | | | | | | | | | | | |
| 149918 | | | | | | | | | 510,712 | 13,8555 | 59859,6 |
| 337857 | 477,627 | 8,42435 | 52404,6 | | 508,31 | 10,0321 | 140191 | | | | |
| 410870 | | | | | | | | | | | |
| 499196 | | | | | | | | | | | |
| 657247 | | | | | | | | | 511,963 | 142183 | 200510 |
| 1,33E+06 | | | | | | | | | 510,421 | 11,0886 | 88477,5 |
| 726681 | | | | | | | | | | | |
| 237718 | | | | | | | | | | | |
| 535334 | | | | | | | | | | | |
| 212933 | | | | | | | | | | | |
| 356016 | | | | | | | | | | | |
| 358310 | | | | | | | | | | | |
| 528490 | | | | | | | | | 510,466 | 13,5453 | 143128 |
| 564258 | | | | | | | | | | | |
| 355732 | | | | | | | | | | | |
| 692748 | | | | | | | | | | | |
| 452518 | | | | | | | | | | | |
| 637156 | | | | | | | | | | | |
| 455759 | | | | | | | | | | | |
| 405402 | | | | | | | | | | | |
| 474096 | | | | | | | | | | | |
| 575690 | | | | | | | | | | | |
| 512907 | | | | | | | | | | | |
| 202623 | | | | | | | | | | | |
| 407504 | | | | | | | | | | | |
| 1,25E+06 | | | | | | | | | | | |
| 642447 | | | | | | | | | | | |
| 414073 | | | | | | | | | | | |
| 489961 | | | | | | | | | | | |
| 954677 | | | | | | | | | | | |
| 443581 | | | | | | | | | | | |
| 553733 | | | | | | | | | | | |
| 447427 | | | | | | | | | | | |
| 442978 | | | | | | | | | | | |
| 689756 | 478,073 | 9,97749 | 94112,9 | | | | | | | | |
| 384778 | | | | | | | | | | | |
| 381053 | | | | | | | | | | | |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 384097 | | | | | | | | | | | |
| 594947 | | | | | | | | | | | |
| 110998 | | | | | | | | | | | |
| 113715 | 479,195 | 6,91007 | 24955,9 | | | | | | 510,193 | 11,7376 | 189272 |
| 116343 | 479,311 | 7,22473 | 27965,5 | | | | | | 509,976 | 11,5529 | 186424 |
| 408063 | | | | | | | | | | | |
| 103049 | | | | | | | | | | | |
| 231623 | | | | | | | | | | | |
| 732191 | | | | | | | | | | | |
| 628931 | | | | | | | | | | | |
| 965862 | | | | | | | | | | | |
| 1,57E+06 | | | | | | | | | | | |
| 474798 | | | | | | | | | | | |
| 626473 | | | | | | | | | | | |
| 455403 | | | | | | | | | | | |
| 662790 | | | | | | | | | | | |
| 517482 | | | | | | | | | | | |
| 521475 | | | | | | | | | | | |
| 532289 | | | | | | | | | | | |
| 632022 | | | | | | | | | | | |
| 745902 | | | | | | | | | | | |
| 863892 | | | | | | | | | | | |
| 490674 | | | | | | | | | | | |
| 1,06E+06 | | | | | | | | | | | |
| 1,05E+06 | | | | | | | | | | | |
| 740168 | | | | | | | | | | | |
| 102241 | | | | | | | | | | | |
| 160543 | 478,808 | 7,66628 | 73377,7 | | | | 508,231 | 9,79608 | 189093 | | |
| 884470 | | | | | | | | | | | |
| 536653 | | | | | | | | | | | |
| 608616 | | | | | | | | | | | |
| 122230 | | | | | | | | | | | |
| 70670,5 | | | | | | | | | | | |
| 33092,4 | | | | | | | | | | | |
| 122797 | | | | | | | | | | | |
| 339658 | | | | | | | | | | | |
| 103659 | | | | | | | | | | | |
| 100530 | | | | | | | | | | | |
| 305963 | | | | | | | | | | | |
| 157983 | | | | | | | | | | | |
| 30346,5 | | | | | | | | | | | |
| 131321 | 478,102 | 8,51421 | 13799,8 | | | | 509,813 | 8,11831 | 20814,2 | | |
| | | | | | | | | | | 509,452 | 9,62617 | 43746,3 |
| 160032 | | | | | | | | | | | |
| | | | | | | | 508,864 | 6,4196 | 10574,9 | | |

Appendix III - Supplementary Table 3. *Cont.*

| Centre | Width | Area | Centre | Width | Area | Centre | Width | Area | Centre | Width | Area | Centre |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 528,069 | 24,9004 | 170416 | | | | | | | |
| 513,645 | 11,0479 | 180155 | | | | | | | | | | |
| 513,569 | 11,6129 | 268893 | | | | | | | | | | |
| 512,186 | 6,56662 | 78693,1 | | | | | | | | | | |
| 515,487 | 13,633 | 65920,5 | | | | | | | | | | |
| 512,136 | 12,765 | 103093 | | | | | | | | | | |
| | | | | | | | | | 559,181 | 19,9376 | 162833 | |
| | | | 527,5 | 16,1395 | 259151 | | | | | | | |
| 514,361 | 23,4813 | 995495 | | | | | | | | | | |
| 512,543 | 8,10731 | 66445,7 | | | | | | | | | | |
| 514,021 | 18,5461 | 461113 | | | | | | | | | | |
| 515,053 | 24,4582 | 907621 | | | | | | | | | | |
| | | | 521,42 | 19,8512 | 64950,3 | | | | | | | |
| | | | 518,606 | 21,3626 | 92741,4 | | | | | | | |
| | | | 517,344 | 16,0013 | 75953,2 | | | | | | | |
| 512,097 | 13,9452 | 165443 | | | | | | | | | | |
| 517,981 | 16,4083 | 54906,9 | | | | | | | | | | |
| | | | 518,999 | 18,1403 | 52680,9 | | | | | | | |
| | | | 519,227 | 27,476 | 114395 | | | | | | | |
| | | | 516,912 | 20,3792 | 176755 | | | | | | | |
| | | | 521,287 | 18,41 | 57160,1 | | | | | | | |
| | | | 520,575 | 22,9289 | 106717 | | | | | | | |
| 516,996 | 14,7574 | 71018,8 | | | | | | | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 515,2 | 17,5401 | 495203 | | | | | | | | |
| 514,94 | 10,0627 | 377930 | | | | | | | | |
| | | | 519,487 | 23,66 | 659096 | | | | | |
| | | | 517,27 | 20,1192 | 430540 | | | | | |
| | | | | | | | | | | |
| | | | 516,12 | 13,9272 | 99009,7 | | | | | |
| | | | 524,66 | 15,2208 | 61217,3 | | | | | |
| | | | 522,329 | 21,2302 | 91195,4 | | | | | |
| 513,241 | 14,7452 | 331951 | | | | | | | | |
| | | | 523,626 | 20,5683 | 67919,6 | | | | | |
| | | | | | | | | | | |
| | | | 521,663 | 21,6068 | 108175 | | | | | |
| 514,087 | 13,8751 | 81326,2 | | | | | | | | |
| | | | 523,254 | 19,7641 | 110921 | | | | | |
| | | | 520,527 | 23,4349 | 236559 | | | | | |
| | | | 522,247 | 28,8464 | 322248 | | | | | |
| | | | 523,337 | 24,4865 | 263012 | | | | | |
| | | | 521,245 | 23,4054 | 237137 | | | | | |
| | | | 519,095 | 20,9229 | 209202 | | | | | |
| | | | 522,937 | 21,5667 | 174688 | | | | | |
| | | | 520,683 | 25,8429 | 490875 | | | | | |
| | | | 521,662 | 28,2049 | 454533 | | | | | |
| | | | 520,151 | 24,6888 | 397881 | | | | | |
| 513,576 | 14,2118 | 313396 | 525,603 | 20,1221 | 302567 | | | | | |
| | | | 521,988 | 23,782 | 203545 | | | | | |
| 519,742 | 22,4767 | 292111 | | | | | | | | |
| | | | 522,714 | 22,8085 | 126509 | | | | | |
| | | | 521,798 | 20,9897 | 116848 | | | | | |
| | | | 520,19 | 26,1212 | 382225 | | | | | |
| | | | 522,455 | 22,6457 | 171438 | | | | | |
| | | | 522,274 | 21,676 | 193639 | | | | | |
| | | | 520,86 | 22,4631 | 209965 | | | | | |
| | | | 522,177 | 23,8419 | 1,48E+06 | | | | | |
| 517,328 | 14,9607 | 108439 | | | | | | | | |
| | | | 522,414 | 21,0234 | 467146 | | | | | 601,799 |
| | | | 527,107 | 31,3882 | 777413 | | | | | 609,075 |
| | | | 522,162 | 24,183 | 956127 | | | | | |
| | | | 524,14 | 28,4459 | 524065 | | | | | |
| | | | 522,055 | 20,3739 | 404160 | | | | | |
| 515,264 | 27,9261 | 4,07E+06 | | | | | | | | |
| | | | 529,326 | 34,5752 | 1,30E+06 | | | | | |
| | | | 523,238 | 37,5897 | 1,35E+06 | | | | | |
| | | | 526,625 | 33,2881 | 1,01E+06 | | | | | |
| 516,394 | 24,5628 | 791768 | | | | 548,342 | 51,7255 | 1,90E+06 | | |
| | | | | | | | | | | 606,72 |
| | | | 528,126 | 31,0846 | 1,42E+06 | | | | | |
| | | | 524,698 | 33,0801 | 1,80E+06 | | | | | |
| | | | | | | | | | | |
| | | | 527,851 | 37,6848 | 1,14E+06 | | | | | |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 533,188 | 43,5923 | 703226 | | | | |
| | | | 521,16 | 22,6832 | 889284 | | | | |
| | | | 525,153 | 25,4951 | 289883 | | | | |
| 517,627 | 24,8055 | 547214 | | | | | | | |
| | | | 522,423 | 24,0005 | 1,48E+06 | | | | |
| | | | 528,622 | 27,8559 | 588371 | | | | 612,479 |
| | | | 525,149 | 24,6735 | 663344 | | | | |
| 513,156 | 13,8834 | 815115 | | | | | | | |
| 515,293 | 22,6182 | 648246 | | | | 545,222 | 49,6118 | 1,30E+06 | |
| | | | 520,033 | 24,2152 | 108229 | | | | |
| | | | 521,642 | 23,1007 | 47279,2 | | | | |
| 512,601 | 16,6214 | 131473 | 529,142 | 16,8696 | 79016,3 | | | | |
| 516,417 | 24,8557 | 228002 | | | | 546,352 | 49,6868 | 292437 | |
| 514,489 | 18,4758 | 64947,2 | | | | | | | |
| | | | 525,713 | 25,1273 | 102144 | | | | |
| | | | 521,55 | 22,6651 | 149473 | | | | |
| | | | 518,951 | 18,3957 | 53659,5 | | | | |
| 513,618 | 14,678 | 123724 | | | | | | | |
| | | | 524,141 | 239609 | 265123 | | | | |
| | | | 523,157 | 19,9958 | 107678 | | | | |
| | | | 517,742 | 21,8683 | 126678 | | | | |
| | | | 516,291 | 24,1582 | 275955 | 547,145 | 48,8624 | 397162 | |
| | | | 522,185 | 26,8537 | 168792 | | | | |
| | | | 523,656 | 38,7733 | 696674 | | | | |
| | | | 522,321 | 33,0238 | 433320 | | | | |
| 512,341 | 14,6657 | 107621 | 527,695 | 27,037 | 168600 | | | | |
| | | | 525,93 | 25,4867 | 278961 | | | | |
| | | | 520,491 | 28,8295 | 551480 | | | | |
| | | | 518,334 | 25,5634 | 479728 | | | | |
| 521,849 | 28,6415 | 329497 | | | | | | | |
| | | | 518,449 | 26,1518 | 378276 | | | | |
| | | | 519,874 | 25,3826 | 238309 | | | | |
| | | | 520,947 | 28,1074 | 253280 | | | | |
| | | | 519,665 | 28,2616 | 418859 | | | | |
| | | | 522,002 | 27,4138 | 220203 | | | | |
| | | | 518,91 | 25,1279 | 375739 | | | | |
| | | | 520,111 | 28,3482 | 482655 | | | | |
| 516,509 | 27,2678 | 1,52E+06 | | | | | | | |
| | | | 516,331 | 22,3016 | 185958 | | | | |
| | | | 519,726 | 24,3101 | 335916 | | | | |
| | | | 519,095 | 23,718 | 144880 | | | | |
| | | | 518,783 | 26,1438 | 391414 | | | | |
| | | | 519,281 | 26,7334 | 291200 | | | | |
| | | | 519,893 | 24,8926 | 209560 | | | | |
| | | | 517,907 | 26,5665 | 409564 | | | | |
| | | | 517,179 | 26,0281 | 508308 | | | | |
| | | | 516,683 | 23,3549 | 696717 | | | | |
| | | | 516,639 | 23,1323 | 706983 | | | | |
| 512,436 | 16,8817 | 305089 | | | | | | | |
| | | | 520,844 | 28,9745 | 192140 | | | | |
| | | | 520,847 | 29,0704 | 191867 | | | | |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 521,231 | 30,7469 | 353060 | | | | | |
| 512,183 | 13,0368 | 190777 | 526,064 | 21,1353 | 139908 | | | | | |
| | | | 519,34 | 29,2514 | 380123 | | | | | |
| | | | 524,896 | 25,8519 | 342264 | | | | | |
| | | | 523,951 | 23,5176 | 283409 | | | | | |
| | | | 518,901 | 25,0949 | 330499 | 546,418 | 43,2666 | 193530 | | |
| | | | 517,714 | 30,0763 | 1,07E+06 | | | | | |
| | | | 518,629 | 26,2294 | 195002 | | | | | |
| | | | 521,13 | 24,7629 | 245530 | | | | | |
| | | | 521,638 | 25,6638 | 216324 | | | | | |
| | | | 521,929 | 24,2884 | 173145 | | | | | |
| | | | 520,686 | 24,5266 | 240022 | | | | | |
| 512,096 | 17,6269 | 382419 | 524,905 | 26,0597 | 550347 | | | | | |
| | | | 521,447 | 26,7581 | 325345 | | | | | |
| | | | 519,632 | 26,5731 | 478066 | | | | | |
| | | | 522,348 | 24,3157 | 234567 | | | | | |
| | | | 520,854 | 28,9398 | 404188 | | | | | |
| | | | 520,832 | 25,5777 | 289333 | | | | | |
| 514,703 | 13,433 | 211194 | 529,452 | 11,5585 | 108193 | | | | | |
| | | | 521,165 | 25,5428 | 263501 | | | | | |
| | | | 522,278 | 25,5875 | 264826 | | | | | |
| | | | 521,468 | 26,7763 | 350387 | | | | | |
| | | | 522,895 | 26,5866 | 304749 | | | | | |
| | | | 521,215 | 26,8074 | 359573 | | | | | |
| | | | 519,938 | 24,2897 | 252531 | | | | | |
| | | | 519,745 | 23,7821 | 292368 | | | | | |
| | | | | | | | | | | |
| | | | | | | 549,34 | 49,3832 | 296858 | | |
| 516,781 | 20,7812 | 195952 | | | | | | | | |
| | | | | | | | | | | |
| | | | 527,13 | 34,0343 | 52785,5 | | | | | |
| | | | 523,981 | 32,9371 | 110157 | | | | | |
| 516,053 | 207481 | 69137,6 | | | | | | | | |
| | | | 526,847 | 20,5371 | 38443,2 | | | | | |
| | | | 523,073 | 22,838 | 39654,2 | | | | | |
| | | | 530,065 | 44,4796 | 116701 | | | | | |
| | | | | | | | | | | |
| | | | | | | 548,851 | 68,8367 | 456277 | | |

Appendix III - Supplementary Table 3. *Cont.*

| Width | Area | Centre | Width | Area | Centre | Width | Area | Centre | Width | Area |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 642,419 | 22,6514 | 310982 | | | | 703,387 | 16,2969 | 2,38E+06 |
| | | 644,606 | 26,8147 | 543167 | | | | 703,163 | 15,8292 | 962352 |
| | | 639,327 | 11,0479 | 247555 | 655,025 | 15,6341 | 139434 | 702,95 | 15,6341 | 1,06E+06 |
| | | 638,984 | 7,24279 | 165875 | 648,125 | 25,3152 | 371981 | 702,923 | 16,4343 | 724484 |
| | | 643,861 | 21,6694 | 202389 | | | | 702,646 | 17,0406 | 1,18E+06 |
| | | 638,827 | 6,19155 | 162153 | 647,614 | 15,0298 | 119972 | 702,816 | 17,0965 | 615719 |
| | | 642,723 | 26,2307 | 351731 | | | | 702,798 | 16,2647 | 699014 |
| | | 640,97 | 25,8246 | 280006 | | | | 703,696 | 16,6032 | 1,45E+06 |
| | | 641,721 | 16,2507 | 340165 | | | | 703,45 | 16,2507 | 1,44E+06 |
| | | 639,929 | 25,8382 | 294509 | | | | 703,116 | 17,5936 | 822466 |
| | | 639,581 | 25,2696 | 507437 | | | | 703,48 | 16,615 | 2,61E+06 |
| | | 638,597 | 24,8214 | 652907 | | | | 703,486 | 16,7496 | 2,47E+06 |
| | | 640,5 | 24,0931 | 651280 | | | | 703,131 | 16,3709 | 1,40E+06 |
| | | 642,865 | 20,751 | 232262 | | | | 699,6 | 15,1432 | 302681 |
| | | 640,522 | 17,9196 | 283153 | | | | 702,76 | 17,0832 | 1,22E+06 |
| | | 639,535 | 23,2628 | 815404 | | | | 702,873 | 16,339 | 1,16E+06 |
| | | 641,886 | 22,3988 | 291647 | | | | 702,84 | 16,6698 | 863265 |
| | | 639,722 | 5,77075 | 273091 | 645,195 | 28,0287 | 598235 | 702,573 | 14,3568 | 725341 |
| | | 646,358 | 33,2931 | 1,48E+06 | | | | 703,406 | 14,8171 | 884101 |
| | | 638,609 | 25,7161 | 3,51E+06 | | | | 702,892 | 14,0336 | 446716 |
| | | 639,14 | 31,2755 | 654639 | | | | 702,599 | 16,1047 | 820931 |
| | | 638,646 | 26,6794 | 1,69E+06 | | | | 703,134 | 15,4903 | 447919 |
| | | 639,414 | 26,4692 | 1,10E+06 | | | | 702,754 | 16,3503 | 623669 |
| | | 638,16 | 31,6711 | 828715 | | | | 703,059 | 16,1863 | 966520 |
| | | 642,228 | 26,2958 | 224048 | | | | 704,317 | 15,9729 | 166986 |
| | | 644,856 | 29,7496 | 164194 | | | | 703,929 | 15,2006 | 137459 |
| | | 647 | 27,7501 | 178223 | | | | 705,441 | 14,591 | 263585 |
| | | 642,965 | 30,1761 | 301565 | | | | 704,538 | 14,5207 | 143765 |
| | | 644,83 | 31,6785 | 154084 | | | | 704,075 | 16,1589 | 192640 |
| | | 646,68 | 33,7129 | 199790 | | | | 703,859 | 15,2718 | 101925 |
| | | 646,051 | 32,9784 | 196681 | | | | 704,746 | 14,9854 | 228151 |
| | | 642,06 | 25,0054 | 303163 | | | | 704,107 | 14,2947 | 125004 |
| | | 643,765 | 30,9884 | 328533 | | | | 704,285 | 14,7429 | 178214 |
| | | 643,838 | 28,2531 | 121459 | | | | 703,985 | 14,7981 | 169742 |
| | | 639,195 | 27,2874 | 1,25E+06 | | | | 704,468 | 12,7366 | 103006 |
| | | 643,53 | 32,332 | 291274 | | | | 704,414 | 13,2576 | 65029,6 |
| | | 644,96 | 34,9566 | 189781 | | | | 704,144 | 14,3984 | 74492,7 |
| | | 642,384 | 31,0979 | 335086 | | | | 705,082 | 13,918 | 91276,5 |
| | | 647,128 | 32,9981 | 241110 | | | | 704,852 | 14,6689 | 132849 |
| | | 645,692 | 31,8225 | 187291 | | | | 704,53 | 14,3945 | 153377 |
| | | 650,253 | 31,8279 | 190169 | | | | 705,095 | 14,5226 | 236036 |
| | | 646,489 | 32,1205 | 385547 | | | | 704,71 | 15,3994 | 301080 |
| | | | | | | | | 703,936 | 17,5493 | 86278,4 |
| | | | | | | | | 704,653 | 18,0119 | 260243 |
| | | 644,812 | 31,5174 | 309130 | | | | 704,47 | 14,4349 | 118263 |
| | | 647,686 | 33,4939 | 249898 | | | | 704,116 | 15,2048 | 201229 |
| | | 645,278 | 33,9021 | 413457 | | | | 704,535 | 14,7755 | 208482 |
| | | | | | | | | 704,248 | 16,517 | 160747 |
| | | 647,679 | 33,9747 | 207996 | | | | 703,853 | 15,4563 | 135672 |
| | | 645,154 | 33,3557 | 358358 | | | | 704,322 | 13,5503 | 145409 |
| | | 643,818 | 32,433 | 278956 | | | | 704,382 | 14,6789 | 174836 |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 641,726 | 28,585 | 834396 | | | | 704,756 | 10,8073 | 41147,7 |
| | | 644,261 | 32,1423 | 337044 | | | | 705,078 | 14,7912 | 130156 |
| | | 643,115 | 30,6702 | 2,53E+06 | | | | 705,245 | 10,8431 | 157043 |
| | | 639,801 | 24,9839 | 2,91E+06 | | | | 705,081 | 12,2415 | 102344 |
| | | 643,632 | 31,0579 | 154220 | | | | 703,889 | 15,4636 | 219921 |
| | | 651,517 | 29,0928 | 139114 | | | | 704,149 | 16,5703 | 125324 |
| | | 647,791 | 34,0436 | 362033 | | | | 705,103 | 14,9939 | 213099 |
| | | 646,968 | 33,4293 | 319570 | | | | 704,848 | 14,5192 | 285719 |
| | | 646,147 | 34,6975 | 284460 | | | | 703,944 | 13,5184 | 98351 |
| | | | | | | | | 704,281 | 16,4533 | 252401 |
| | | 645,532 | 28,7366 | 211063 | | | | 704,618 | 14,4598 | 316057 |
| | | 646,628 | 31,0072 | 240649 | | | | 704,707 | 14,0345 | 119356 |
| | | 645,489 | 32,1423 | 309960 | | | | 704,379 | 15,2409 | 174432 |
| | | 646,621 | 36,1228 | 405746 | | | | 704,398 | 15,1352 | 285632 |
| | | 644,726 | 28,765 | 279460 | | | | 704,156 | 14,2035 | 125733 |
| | | 646,512 | 31,5567 | 260540 | | | | 704,737 | 14,4413 | 250279 |
| | | | | | 648,793 | 34,9949 | 589002 | 706,148 | 12,4693 | 106822 |
| | | | | | 648,104 | 34,9383 | 636261 | 706,093 | 12,8382 | 131215 |
| | | | | | 645,802 | 34,3099 | 815881 | 705,209 | 14,0179 | 195818 |
| | | | | | 648,618 | 35,7153 | 641112 | 705,988 | 14,8032 | 183611 |
| | | | | | 647,242 | 36,218 | 625037 | 704,971 | 14,8757 | 251273 |
| | | | | | 648,263 | 38,1241 | 707124 | 705,551 | 11,7501 | 82829 |
| | | | | | 650,15 | 37,8136 | 742514 | 706,154 | 13,0412 | 191510 |
| | | 642,396 | 25,8067 | 1,12E+06 | | | | 705,54 | 13,9778 | 162627 |
| | | | | | 646,054 | 34,4366 | 917162 | 706,241 | 13,752 | 179949 |
| | | | | | 644,205 | 31,6171 | 1,17E+06 | 705,91 | 11,8466 | 131168 |
| | | 641,315 | 26,63 | 2,64E+06 | | | | 705,909 | 11,0104 | 129906 |
| | | | | | 649,366 | 38,6754 | 925993 | 706,409 | 11,4308 | 97287,1 |
| | | 639,071 | 21,1956 | 514568 | 657,185 | 32,678 | 508298 | 706,13 | 14,1246 | 174420 |
| | | 640,035 | 17,2431 | 304602 | 658,747 | 26,6467 | 304051 | 705,482 | 12,9481 | 131958 |
| | | | | | 649,452 | 38,1285 | 608244 | 705,965 | 12,8619 | 85943,5 |
| | | 639,469 | 21,0809 | 547024 | 659,275 | 28,4054 | 507743 | 705,511 | 13,3714 | 154647 |
| | | | | | 648,102 | 36,1021 | 643449 | 706,787 | 9,35717 | 53100,1 |
| | | | | | 649,56 | 36,5732 | 719645 | 705,558 | 14,8864 | 265182 |
| | | | | | 649,241 | 36,3243 | 719489 | 705,535 | 13,7828 | 188360 |
| | | 636,629 | 28,3823 | 1,66E+07 | | | | 703,262 | 13,5782 | 614064 |
| | | 636,998 | 26,2243 | 811168 | | | | 701,977 | 18,8654 | 1,04E+06 |
| 17,8056 | 25199.5 | 636,247 | 36,3524 | 3,39E+06 | | | | 701,547 | 13,8571 | 558504 |
| 18,6495 | 186408 | 633,75 | 21,5689 | 630288 | | | | 702,156 | 24,5441 | 1,89E+06 |
| | | 637,141 | 32,7475 | 6,29E+06 | | | | 702,21 | 12,0287 | 348169 |
| | | 639,631 | 31,0942 | 879355 | | | | 701,618 | 18,1063 | 760261 |
| | | 636,597 | 28,3363 | 3,52E+06 | | | | 701,856 | 16,4365 | 742766 |
| | | 635,396 | 30,7567 | 1,08E+07 | | | | 702,574 | 14,9094 | 603447 |
| | | 635,392 | 27,5609 | 4,88E+06 | | | | 702,436 | 19,597 | 1,38E+06 |
| | | 637,227 | 24,2247 | 1,63E+06 | | | | 702,439 | 18,908 | 1,03E+06 |
| | | 636,298 | 27,7774 | 1,39E+06 | | | | 702,051 | 18,7244 | 1,08E+06 |
| | | 635,845 | 17,4244 | 501380 | | | | 702,292 | 26,6537 | 2,90E+06 |
| 25,7853 | 666573 | 635,497 | 32,0728 | 1,25E+06 | | | | 701,751 | 16,5232 | 845409 |
| | | 637,009 | 30,3842 | 3,04E+06 | | | | 702,034 | 16,7332 | 792274 |
| | | 635,688 | 29,4735 | 4,55E+06 | | | | 702,725 | 17,0456 | 766514 |
| | | 638,473 | 25,7832 | 1,85E+06 | | | | 702,185 | 16,4503 | 838178 |
| | | 636,794 | 27,0555 | 2,19E+06 | | | | 702,038 | 18,0861 | 1,05E+06 |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 638,161 | 19,9321 | 1,07E+06 | | | | 702,007 | 18,4674 | 1,35E+06 |
| | | 637,153 | 27,9743 | 8,54E+06 | | | | 702,742 | 13,9261 | 790646 |
| | | 635,677 | 27,1867 | 1,72E+06 | | | | 702,105 | 18,4056 | 993686 |
| | | 636,717 | 28,7069 | 3,04E+06 | | | | 702,117 | 15,5522 | 422080 |
| | | 636,638 | 28,4677 | 1,66E+07 | | | | 703,202 | 13,4001 | 597656 |
| 23,3371 | 253424 | 637,083 | 20,3796 | 604060 | | | | 701,841 | 20,2701 | 1,64E+06 |
| | | 633,5 | 31,2443 | 3,34E+06 | | | | 702,565 | 19,5151 | 1,48E+06 |
| | | 638,228 | 28,5423 | 1,40E+06 | | | | 702,401 | 15,9899 | 663896 |
| | | 636,217 | 23,1975 | 1,35E+06 | | | | 702,266 | 20,9382 | 1,91E+06 |
| | | 639,357 | 27,9553 | 327197 | | | | 703,932 | 12,4146 | 42915 |
| | | 643,877 | 33,6694 | 208949 | | | | 702,915 | 14,3843 | 89588,7 |
| | | 636,87 | 22,9543 | 619221 | 655,953 | 22,186 | 115525 | 703,798 | 12,9897 | 70763,8 |
| | | 644,469 | 29,1625 | 248426 | | | | 703,257 | 13,165 | 80407 |
| | | 639,382 | 23,8053 | 399825 | | | | 703,044 | 16,6464 | 263410 |
| | | 637,386 | 19,1681 | 104569 | 655,74 | 25,5635 | 91198,3 | 703,27 | 13,3177 | 53692,6 |
| | | 638,295 | 17,9779 | 204204 | | | | 703,747 | 16,9327 | 142259 |
| | | 639,034 | 25,2235 | 363460 | | | | 703,134 | 16,7246 | 201390 |
| | | 640,814 | 24,3918 | 195984 | | | | 703,156 | 16,3668 | 281124 |
| | | | | | | | | 703,216 | 20,2954 | 415210 |
| | | 637,702 | 25,061 | 1,34E+06 | | | | 703,09 | 14,4593 | 143829 |
| | | 637,078 | 23,167 | 585820 | 656,217 | 21,4481 | 98631,3 | 703,085 | 13,8737 | 111310 |
| | | 638,004 | 29,1643 | 791308 | | | | 702,315 | 14,72285 | 153061 |
| | | 638,938 | 23,8005 | 447491 | | | | 703,075 | 17,1465 | 303848 |
| | | 643,567 | 32,7973 | 371919 | | | | 703,984 | 15,8265 | 159750 |
| | | 641,007 | 27,331 | 425593 | | | | 703,892 | 14,9646 | 245625 |
| | | 640,542 | 27,7796 | 405908 | | | | 703,686 | 15,8665 | 226534 |
| | | 640,198 | 31,1604 | 566858 | | | | 703,544 | 14,686 | 192986 |
| | | 642,213 | 32,4674 | 622651 | | | | 703,774 | 16,1394 | 226775 |
| | | 640,207 | 26,5737 | 717629 | | | | 704,443 | 16,3411 | 164499 |
| | | 640,107 | 31,5988 | 1,97E+06 | | | | 703,768 | 12,0771 | 106124 |
| | | 644,234 | 33,6017 | 694860 | | | | 704,193 | 13,9331 | 190803 |
| | | 643,425 | 33,1989 | 671739 | | | | 705,14 | 14,7303 | 155611 |
| | | 641,842 | 32,4255 | 597041 | | | | 703,448 | 14,5953 | 176630 |
| | | 641,747 | 30,7099 | 332438 | | | | 703,9 | 16,5857 | 233418 |
| | | 640,618 | 29,6217 | 1,07E+06 | | | | 704,853 | 14,2197 | 139687 |
| | | 643,178 | 31,4702 | 346193 | | | | 704,22 | 15,4421 | 196436 |
| | | 638,502 | 27,3405 | 1,48E+06 | | | | 704,993 | 13,9964 | 147990 |
| | | 643,912 | 34,3905 | 866544 | | | | 704,186 | 13,2432 | 151402 |
| | | 638,824 | 30,5369 | 4,32E+06 | | | | 704,549 | 9,72333 | 74807,8 |
| | | 640,922 | 28,4329 | 377032 | | | | 702,868 | 16,3695 | 232731 |
| | | 644,783 | 37,2009 | 1,03E+06 | | | | 704,511 | 12,8663 | 124514 |
| | | 640,778 | 28,675 | 391330 | | | | 703,194 | 15,2865 | 248670 |
| | | 641,659 | 34,8321 | 1,11E+06 | | | | 704,16 | 13,6566 | 159166 |
| | | 639,226 | 23,9178 | 348619 | | | | 703,789 | 17,4738 | 387065 |
| | | 644,387 | 27,6368 | 217529 | | | | 704,629 | 15,9142 | 171200 |
| | | 639,362 | 26,1278 | 729945 | | | | 704,711 | 16,1305 | 194232 |
| | | 638,402 | 23,3947 | 594034 | | | | 704,635 | 19,8493 | 380232 |
| | | 639,682 | 28,1026 | 1,69E+06 | | | | 704,277 | 12,7413 | 112856 |
| | | 639,679 | 28,0378 | 1,69E+06 | | | | 704,282 | 12,757 | 112558 |
| | | 640,492 | 30,8006 | 594482 | | | | 704,141 | 11,3832 | 76085,7 |
| | | 640,67 | 28,2855 | 275297 | | | | 703,022 | 15,8167 | 217934 |
| | | 640,67 | 28,2914 | 275390 | | | | 703,022 | 15,8176 | 217955 |

Appendix III - Supplementary Table 3. *Cont.*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 640,775 | 25,4713 | 530596 | | | | 704,233 | 14,7618 | 188971 |
| | 639,229 | 24,8946 | 572686 | | | | 704,396 | 15,3721 | 135755 |
| | 639,573 | 22,6281 | 442309 | | | | 704,509 | 17,8323 | 246187 |
| | 639,269 | 19,9499 | 240193 | | | | 704,266 | 19,992 | 183548 |
| | 639,341 | 20,23 | 243190 | | | | 704,282 | 19,6522 | 175709 |
| | 640,726 | 19,5998 | 267637 | | | | 705,108 | 17,4348 | 247169 |
| | 637,885 | 26,2114 | 1,36E+06 | | | | 705,547 | 17,316 | 155132 |
| | 636,826 | 25,1704 | 324954 | | | | 703,927 | 18,5708 | 246240 |
| | | | | 648,519 | 38,4451 | 702696 | 705,768 | 14,8901 | 173137 |
| | | | | 652,271 | 40,6505 | 596403 | 705,905 | 14,9727 | 180749 |
| | 646,889 | 37,9295 | 562216 | | | | 705,863 | 13,2048 | 110194 |
| | | | | 647,876 | 37,5215 | 623681 | 705,306 | 12,33 | 84412,8 |
| | 640,511 | 32,8211 | 2,08E+06 | | | | 706,225 | 9,65633 | 81607,5 |
| | | | | 647,732 | 38,0729 | 771153 | 705,514 | 14,544 | 181339 |
| | | | | 644,12 | 37,1366 | 1,09E+06 | 704,864 | 12,1459 | 95350,6 |
| | | | | 648,981 | 38,1533 | 738624 | 705,479 | 10,86 | 85822,1 |
| | 637,012 | 21,1455 | 454904 | 656,16 | 31,3044 | 585116 | 706,216 | 8,87 | 116983 |
| | 636,536 | 21,8926 | 356795 | 655,533 | 27,4994 | 464953 | 705,908 | 11,5964 | 111120 |
| | | | | 647,16 | 38,2599 | 567963 | 705,364 | 13,5248 | 145981 |
| | | | | 650,091 | 39,4557 | 718719 | 705,837 | 13,6471 | 87778,8 |
| | | | | 650,208 | 39,387 | 712942 | 705,563 | 12,7227 | 144268 |
| | | | | 647,277 | 37,4323 | 815819 | 705,394 | 12,1203 | 143698 |
| | | | | 648,016 | 33,5944 | 292007 | 705,767 | 15,357 | 224032 |
| | | | | 646,78 | 39,2955 | 1,05E+06 | 705,594 | 12,531 | 110799 |
| | | | | 645,873 | 39,532 | 915460 | 705,45 | 11,9676 | 106297 |
| | | | | 648,321 | 39,5429 | 852871 | 704,803 | 14,2282 | 152219 |
| | 641,397 | 31,5941 | 102219 | | | | 702,739 | 15,5949 | 110334 |
| | 642,059 | 26,8572 | 108554 | | | | 700,834 | 18,4608 | 233869 |
| | 644,842 | 29,0308 | 60348,7 | | | | 702,168 | 14,0674 | 129047 |
| | 638,22 | 15,3056 | 320571 | 650,635 | 5,97176 | 16349,8 | 701,182 | 16,8161 | 773499 |
| | 639,361 | 10,9786 | 192830 | | | | 701,946 | 15,9546 | 799741 |
| | 638,032 | 26,0442 | 1,09E+06 | | | | 701,931 | 15,9984 | 711123 |
| | 639,681 | 24,7712 | 449498 | | | | 702,469 | 15,8912 | 708406 |
| | 640,813 | 28,1334 | 118348 | | | | 702,676 | 15,1473 | 183032 |
| | 645,101 | 31,2358 | 106331 | | | | 703,082 | 15,3217 | 164365 |
| | 643,229 | 25,2838 | 78975,9 | | | | 702,939 | 14,738 | 98988,8 |
| | 643,992 | 31,203 | 120177 | | | | 703,418 | 16,0763 | 227930 |
| | 646,336 | 302869 | 152494 | | | | 703,639 | 14,973 | 116306 |
| | 646,335 | 32,6513 | 132540 | | | | 703,307 | 15,1793 | 177501 |
| | 639,174 | 29,3056 | 122191 | | | | 703,141 | 16,3401 | 236292 |
| | 640,196 | 26,2046 | 110536 | | | | 703,206 | 15,8615 | 176633 |
| | 641,823 | 28,0437 | 160821 | | | | 703,904 | 15,7078 | 252073 |
| | 639,763 | 24,9976 | 61832,2 | | | | 703,363 | 16,0867 | 226059 |
| | 638,6 | 21,8103 | 95710,8 | | | | 703,381 | 16,7874 | 225419 |
| | 639,727 | 27,1999 | 140404 | | | | 702,602 | 15,8474 | 230866 |
| | 638,287 | 26,1858 | 102584 | | | | 703,226 | 16,5721 | 304047 |
| | 643,145 | 16,7459 | 27177,2 | | | | 703,767 | 16,3573 | 269663 |
| | 638,699 | 25,5687 | 102467 | | | | 703,591 | 16,8859 | 288178 |

Appendix III - Supplementary Table 4. Raman spectroscopy polymorph identification in randomly chosen $TiO_2$ crystals from fossils (3D Arumberia mats) and sedimentary matrix

| Date of analysis | Series | Point | Static center | Pot | Mineral/Structure | Identified polymorph |
|---|---|---|---|---|---|---|
| 2018_08 | Af236-2-Region1 | 1 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region1 | 2 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region1 | 3 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region1 | 4 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region1 | 5 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region1 | 6 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region1 | 7 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region1 | 8 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region1 | 9 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region1 | 10 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region1 | 11 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region1 | 12 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region1 | 13 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region1 | 14 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region1 | 15 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region1 | 16 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region1 | 17 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region1 | 18 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region1 | 19 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region1 | 20 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region1 | 1 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region1 | 2 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region1 | 3 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region1 | 4 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region1 | 5 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region1 | 6 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region1 | 7 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region1 | 8 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region1 | 9 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region1 | 10 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region1 | 11 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region1 | 12 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region1 | 13 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region1 | 14 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region1 | 15 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region1 | 16 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region1 | 17 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region1 | 18 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region1 | 19 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region1 | 20 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region2 | 1 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 2 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 3 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 4 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 5 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 6 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 7 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 8 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 9 | 750 | 5% | $TiO_2$ Fossil | Rutile |
| 2018_08 | Af236-2-Region2 | 10 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 11 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 12 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 13 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 14 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 15 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 16 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 17 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 18 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 19 | 750 | 5% | $TiO_2$ Fossil | Anatase |

Appendix III - Supplementary Table 4. *Cont.*

| | | | | | | |
|---|---|---|---|---|---|---|
| 2018_08 | Af236-2-Region2 | 20 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 21 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 22 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 23 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 24 | 750 | 5% | $TiO_2$ Fossil | Rutile |
| 2018_08 | Af236-2-Region2 | 25 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 26 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 27 | 750 | 5% | $TiO_2$ Fossil | Rutile |
| 2018_08 | Af236-2-Region2 | 28 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 29 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region2 | 30 | 750 | 5% | $TiO_2$ Fossil | Rutile |
| 2018_08 | Af236-2-Region2 | 1 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region2 | 2 | 750 | 5% | $TiO_2$ Matrix | Rutile |
| 2018_08 | Af236-2-Region2 | 3 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region2 | 4 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region2 | 5 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region2 | 6 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region2 | 7 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region2 | 8 | 750 | 5% | $TiO_2$ Matrix | Rutile |
| 2018_08 | Af236-2-Region2 | 9 | 750 | 5% | $TiO_2$ Matrix | Rutile |
| 2018_08 | Af236-2-Region2 | 10 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region2 | 11 | 750 | 5% | $TiO_2$ Matrix | Rutile |
| 2018_08 | Af236-2-Region2 | 12 | 750 | 5% | $TiO_2$ Matrix | Rutile |
| 2018_08 | Af236-2-Region2 | 14 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region2 | 15 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region2 | 16 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region2 | 17 | 750 | 5% | $TiO_2$ Matrix | Rutile |
| 2018_08 | Af236-2-Region2 | 18 | 750 | 5% | $TiO_2$ Matrix | Rutile |
| 2018_08 | Af236-2-Region2 | 19 | 750 | 5% | $TiO_2$ Matrix | Rutile |
| 2018_08 | Af236-2-Region2 | 20 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region2 | 21 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region2 | 22 | 750 | 5% | $TiO_2$ Matrix | Rutile |
| 2018_08 | Af236-2-Region2 | 23 | 750 | 5% | $TiO_2$ Matrix | Rutile |
| 2018_08 | Af236-2-Region2 | 24 | 750 | 5% | $TiO_2$ Matrix | Rutile |
| 2018_08 | Af236-2-Region2 | 25 | 750 | 5% | $TiO_2$ Matrix | Rutile |
| 2018_08 | Af236-2-Region2 | 26 | 750 | 5% | $TiO_2$ Matrix | Rutile |
| 2018_08 | Af236-2-Region2 | 27 | 750 | 5% | $TiO_2$ Matrix | Rutile |
| 2018_08 | Af236-2-Region2 | 28 | 750 | 5% | $TiO_2$ Matrix | Rutile |
| 2018_08 | Af236-2-Region2 | 29 | 750 | 5% | $TiO_2$ Matrix | Rutile |
| 2018_08 | Af236-2-Region2 | 30 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region3 | 1 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region3 | 2 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region3 | 3 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region3 | 4 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region3 | 5 | 750 | 5% | $TiO_2$ Fossil | Anatase and rutile |
| 2018_08 | Af236-2-Region3 | 6 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region3 | 7 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region3 | 8 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region3 | 9 | 750 | 5% | $TiO_2$ Fossil | Rutile |
| 2018_08 | Af236-2-Region3 | 10 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region3 | 11 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region3 | 12 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region3 | 13 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region3 | 14 | 750 | 5% | $TiO_2$ Fossil | Anatase and rutile |
| 2018_08 | Af236-2-Region3 | 15 | 750 | 5% | $TiO_2$ Fossil | Anatase |
| 2018_08 | Af236-2-Region3 | 16 | 750 | 5% | $TiO_2$ Fossil | Anatase and rutile |
| 2018_08 | Af236-2-Region3 | 1 | 750 | 5% | $TiO_2$ Matrix | Rutile |
| 2018_08 | Af236-2-Region3 | 2 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region3 | 3 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region3 | 4 | 750 | 5% | $TiO_2$ Matrix | Rutile |

Appendix III - Supplementary Table 4. *Cont.*

| | | | | | | |
|---|---|---|---|---|---|---|
| 2018_08 | Af236-2-Region3 | 5 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region3 | 6 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region3 | 7 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region3 | 8 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region3 | 9 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region3 | 10 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region3 | 11 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region3 | 12 | 750 | 5% | $TiO_2$ Matrix | Anatase |
| 2018_08 | Af236-2-Region3 | 13 | 750 | 5% | $TiO_2$ Matrix | Rutile |
| 2018_08 | Af236-2-Region3 | 14 | 750 | 5% | $TiO_2$ Matrix | Rutile |
| 2018_08 | Af236-2-Region3 | 15 | 750 | 5% | $TiO_2$ Matrix | Rutile |
| 2018_08 | Af236-2-Region3 | 16 | 750 | 5% | $TiO_2$ Matrix | Rutile |

| | **Randomly chosen grains of $TiO_2$** | | | |
|---|---|---|---|---|
| | **Anatase** | **Rutile** | **Both** | **Total** |
| **Fossil** | 58 | 5 | 3 | 66 |
| **Matrix/Cement** | 43 | 22 | 0 | 65 |

**TiO2 disseminated in clays (based on data presented in the Supplementary Table 3)**

| | | **Matrix** | | **Fossils** | |
|---|---|---|---|---|---|
| | | **Anatase** | **Total points** | **Anatase** | **Total points** |
| 2017_06B | Region 1 | 6 | 18 | 21 | 21 |
| 2018_08 | Region 2 | 5 | 6 | 5 | 5 |
| 2018_08 | Region 1 | 9 | 20 | 16 | 16 |
| 2018_08 | Region 2 | 8 | 30 | 21 | 21 |
| 2018_08 | SDSL | 9 | 19 | 17 | 18 |
| | **Total** | **37** | **93** | **80** | **81** |